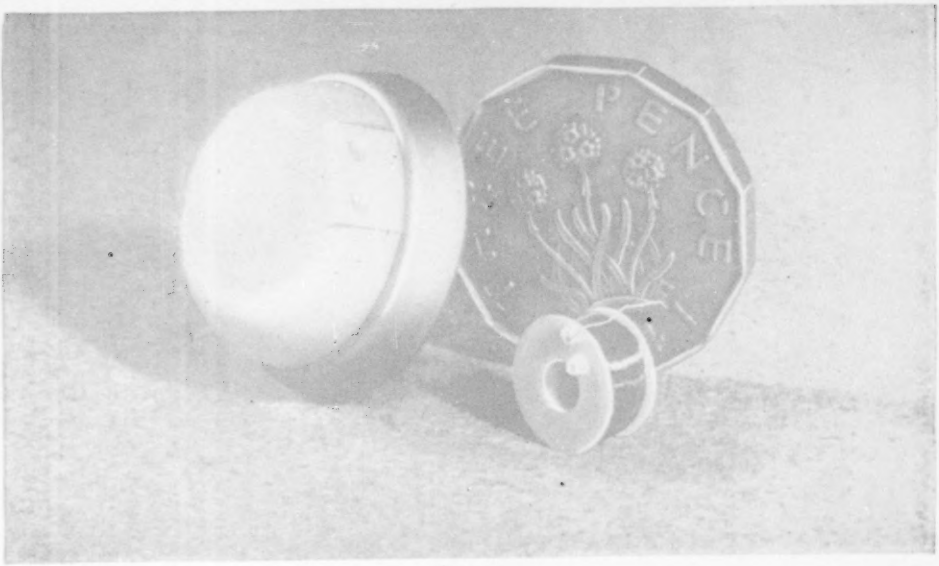
WIRELESS ENGINEER

THE JOURNAL OF RADIO RESEARCH & PROGRESS

APRIL 1951

VOL. XXVIII No. 331 TWO SHILLINGS AND SIXPENCE



WORLD'S SMALLEST 5000-TURN COIL

There are 250 feet of BICC 49 SWG Enamelled Winding Wire in this coil — the smallest 5000-turn coil in the World. Its total weight — including Polystyrene bobbin — is only ·76 grammes!

These coils are used by Messrs. Amplivox Ltd., making their Deaf Aid earphones even less conspicuous than ever. BICC manufacture a wide range of winding wires and strips for every need — from tiny Deaf Aids to heavy-duty alternators and motors. Let us send you further information in Publication No. 266S.

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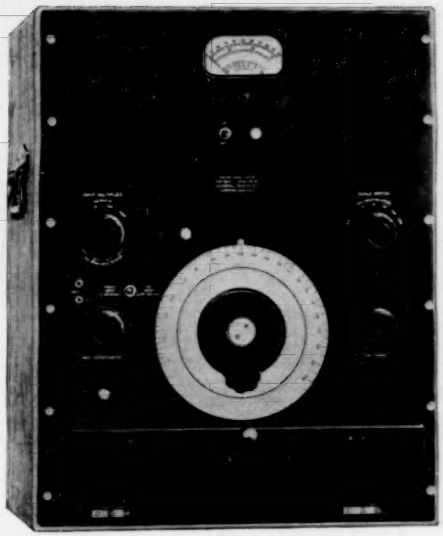

INPUT VOLTAGE RANGE 1,000,000-1

THIS analyser offers the simplest, most accurate and most direct method of measuring the amplitude and frequency of the components of any complex electrical waveform.

In its essentials it consists of a heterodyne-type vacuum-tube voltmeter with a highly selective i-f filter using three quartz bars. At only 60 cycles from resonance the attenuation is down by 75 decibels, yet tuning is very easy by virtue of the 4-cycle flat-top characteristic at resonance. Standards for both voltage and frequency are built into the analyser and can be used to check its calibration at any time.

The Type 736-A Wave Analyser is ideally suited for hundreds of types of harmonic-distortion measurements on any type of audio apparatus, broadcast receivers and transmitters, telephone and public address systems, oscillators, amplifiers and other vacuum-tube circuits; hum measurements on a-c operated communications equipment; harmonic-induction studies on telephone lines.

SPECIFICATIONS

FREQUENCY RANGE: 20 to 16,000 cycles.

SELECTIVITY: About 4 cycles flat-top band width. Response is down 15 db at 5 cycles, 30 db at 10 cycles, 60 db at 30 cycles from peak.

VOLTAGE RANGE: 300 microvolts to 300 volts full scale. Over-all range is divided into four major ranges, each of which is divided into seven scale ranges.

VOLTAGE ACCURACY: Within ± 5% on all ranges.

HUM: Suppressed by at least 75 db.

INPUT IMPEDANCE: 1 megohm for direct voltage measurements; 100,000 ohms with input potentiometer.

ACCURACY OF FREQUENCY CALIBRATION: ± (2% + 1 cycle)

BUILT-IN CALIBRATORS: For both voltage and frequency.

WRITE FOR COMPLETE DATA ON THIS WAVE ANALYSER

The "G.R" Type 736-A Wave-analyser is merely one of a more or less complete range of Electrical and Radio Laboratory Measurement Instruments. The entire range is described in Catalogue "L"—228 pages—free on request.

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BRIEF SPECIFICATION

FREQUENCY: 20 c/s—20 kc/s.
ACCURACY: ±1% or better.
OUTPUT LEVEL: 1W or 10mW into 600 ohms, selected by means of a switch.
ATTENUATORS: 7 steps of 10 db plus 12 db continuously variable.
HARMONICS: 1·75% total at 1 W above 40 c/s 1·0% total at 10 mW above 40 c/s.
HUM LEVEL: 50 db below output level.
DIMENSIONS: 20½-in x 12½-in x 11-in bench mounting — can be supplied for 19-in rack mounting if required.

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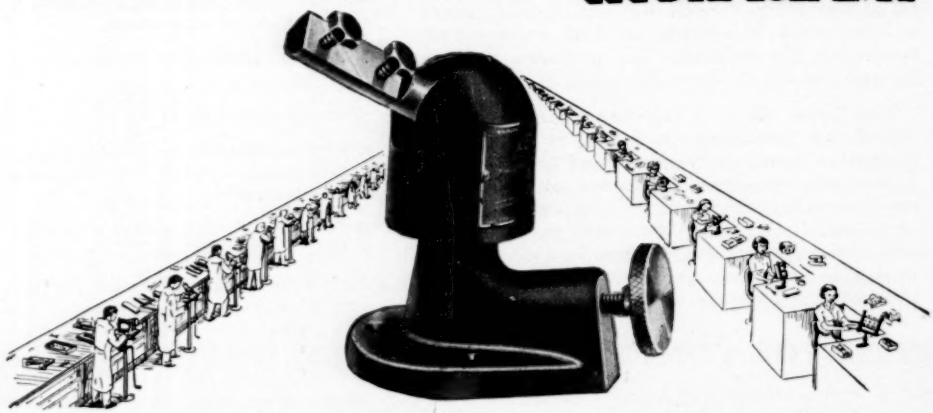

but it pays you back—by saving them! Ten per cent can be easily saved by "Hydraclamping" your radio assemblies for production line build up, also for inspection and maintenance. Our catalogue will show you how.

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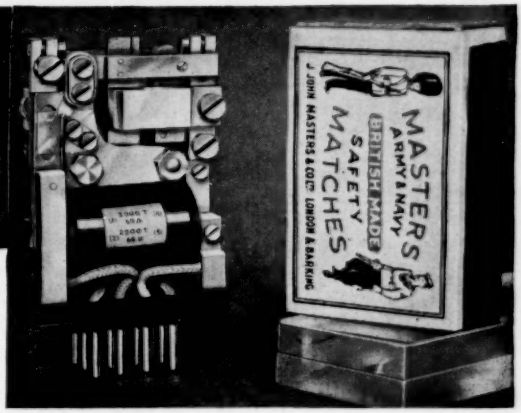
CARPENTER POLARIZED RELAY TYPE 5



MAGNETIC polepieces constitute main frame and carry all other components. Hence no space is wasted on a frame structure and great rigidity and high thermal stability is secured.

Axis of vibration of armature passes through centre of gravity, hence absence of positional error and virtual immunity from effect of vibration.

The only adjustment required is that of contact adjustment screws. No contact chatter.

Two generic types of the Relay are made, each of which may be had on either plug or solder tag base as follows:—

TYPE 5A Lightly side stable high sensitivity model, plug-in base, 12 pins. When adjusted to a static gap of ·002 ins. this model has the following characteristics:—

Side stability (in absence of signal current) 4 grammes. Minimum excitation 2·5 ampere turns R.M.S. at 50 c/s. Working excitation for robust operation 4 ampere turns* R.M.S. at 50 c/s.

Contact Pressure at 4 ampere turns R.M.S. 12 grammes. Maximum speed without bias disturbance or contact chatter, 60 c/s. At about 65 c/s. there is some bias, of the order of 5% but above this the Relay works faultlessly up to about 120 c/s.

TYPE 5C As Type 5A but with soldering tags instead of plug-in base.

TYPE 5B Centre stable model, plug-in base 12 pins. With total contact gap of ·002 ins. (i.e. ·001 in. on either side) this model has the following characteristics:—

Centre stability 3 grammes.
Minimum excitation 2·5 ampere turns D.C.
Minimum excitation 3·0 ampere turns R.M.S. at 50 c/s.
Working excitation for robust operation 4 ampere turns* R.M.S. at 50 c/s.

TYPE 5D As Type 5B but with soldering tags instead of plug-in base.

A number of standard windings is available up to a maximum of 19,000 turns. A maximum of four separate coils is possible.

Dimensions with cover but excluding wiring tags:

HEIGHT	$2\frac{3}{16}$"	**56 mm.**
WIDTH	$1\frac{7}{16}$"	**37 mm.**
DEPTH	$\frac{3}{4}$"	**19 mm.**
WEIGHT	**4.8 ozs.**	**137 gm.**

**4 ampere turns corresponds to about 2mVa at 50 c/s. 0·12mW D.C.*

Complete details available on request.

Manufactured by the Sole Licensees:

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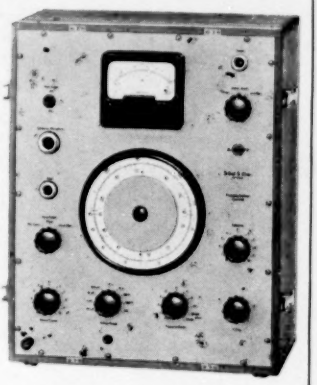
FREQUENCY ANALYZER

Type 2105

operates on the degeneration principle and has a constant percentage bandwidth. The analyzer is applicable to all kinds of acoustical and vibration technical research, and can be used for the measurement and analysis of electrical voltages and as an indicating instrument in all accurate bridge measurements. The instrument is also excellent for measuring sound pressure and sound levels with the aid of a precision microphone, for example our Condenser Microphone 4111.



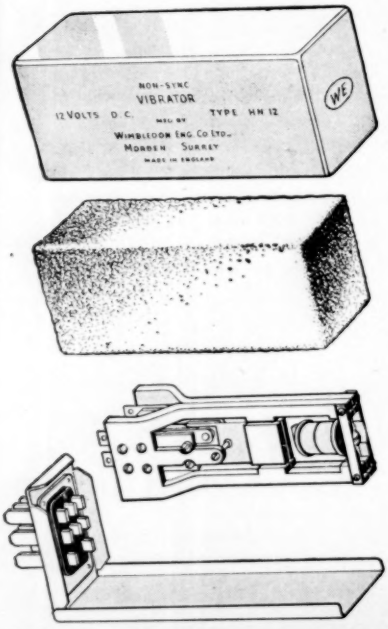
Specification :

Frequency Range: 47-12,000 c/s.
Selectivity: Variable from 0 to max. selectivity, which is about 40 db one octave off the peak.
Frequency Accuracy: Better than 1%.
Frequency Response Characteristics: As a linear amplifier flat from 30 to 15,000 c/s as an analyzer with an octave selectivy of 35 db the amplification of the adjusted frequency is constant within ±1 db. Weighting characteristics at 30-60 phons and 60-130 phons.
Amplification: Full deflection for 100 microvolts. May be attenuated in steps of 20 db.
A.C.-Hum: Approximately 2 microvolts, referring to the input terminals at maximum gain.
Meter: Logarithmic scale, conveniently illuminated.
Scales: From 0 to 100 microvolts and from −10 to + 20 db.
Condenser Microphone 4111 and Artificial Ear 4109 can be connected directly. All necessary voltages are supplied by the analyzer. Noise levels down to 25 phons are measurable.
Blocking Network 1602 can be connected in order to block-out the fundamental for analyzing harmonics down to 0·01%.
Dimensions: 20 (height) × 16 (width) × 8 (depth excl. dials) inches.

Manufactured by :

Brüel & Kjær

Nærum, Denmark.



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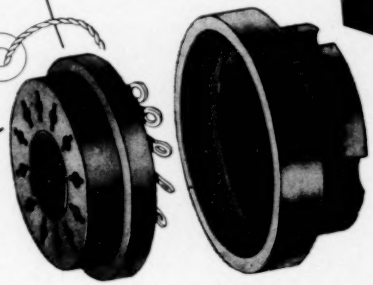

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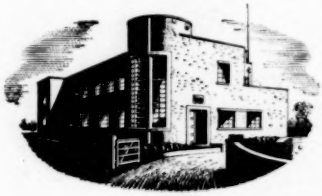

A GREAT NAME

paves the way to greater knowledge

Marconi's acknowledged leadership in the whole field of radio, as we know it today, is based on the sure foundation of scientific training. Fifty years ago Marconi's established the world's first school of wireless engineering, a source of knowledge to which have come students of all colours, classes and creeds from all the corners of the earth; a small building devoted not to technical instruction alone, but also to suggesting the wider potentialities of radio for man's good in the very small and troubled world in which we live.

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MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED · MARCONI HOUSE · CHELMSFORD · ESSEX

Type G10/240E

NEW *Standard electronic counters*

count up to 20,000 digits per second

TWO new *Standard* gas-discharge tubes for electronic digital counters greatly simplify counting circuits and safeguard circuit efficiency. A single G10/240E tube (shown on left), is capable of counting digits at a rate of greater than 20,000 per second.

OPERATION The basic tube of the pair, type G10/240E is a uni-directional 10 point cold-cathode gas tube counter consisting of a single anode, 10 internally joined transfer electrodes and 10 cathodes.

The tube operates from a supply voltage of 330 + 20 volts, and bias potentials are required for transfer and shield electrodes, which may be derived from potentiometers from this high tension supply. The design of the tube is such that, by the application of a negative pulse to the transfer electrode, the discharge to whatever cathode is alight is extinguished and the discharge is started to the adjacent cathode. A single pulse therefore is all that is necessary for counting purposes. The discharge will only move in one direction.

With the appropriate circuit, a minimum output signal of 40 volts can be obtained across the cathode resistance, which is sufficient to operate the G1/370K, which acts as a coupling tube between successive G10/240E tubes in a decimal counter.

The G1/370K is a miniature cold-cathode trigger tube having a permanent priming discharge, as a result of which the delay in firing is reduced to a very low figure and in which deionisation times of less than 30 microseconds enable the tube to operate up to the maximum speed of the G10/240E counter.

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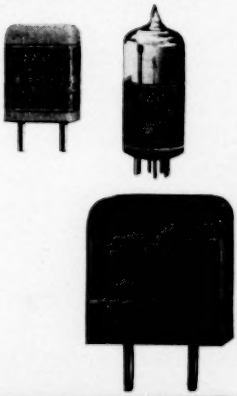
When the requirement is exceptionally urgent, phone Middleton (Lancs.) 2424 or Temple Bar 4669 (London).



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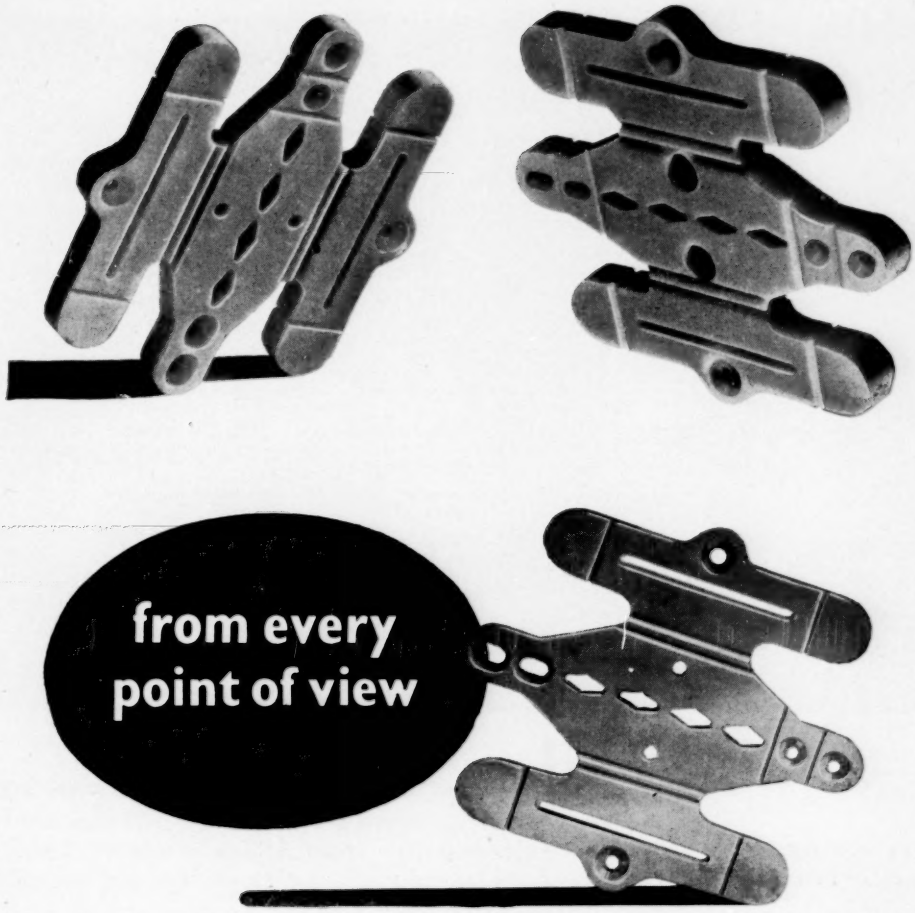

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S.P.66

LOW FREQUENCY SIGNAL GENERATOR

TYPE 702

THIS Low Frequency Signal Generator employs a resistance-capacity oscillator circuit to provide stable output voltages of pure waveform over the frequency range 30 c/s-30 kc/s.

A screened and balanced transformer is provided to enable balanced, unbalanced and fully floating outputs to be obtained, the source impedance under all three conditions being 600 ohms.

PRICE £75

A single level control enables the output to be set to any desired value, and a 600 ohm constant impedance output attenuator provides steps of 20, 40 and 60 db of attenuation.

The output voltage is monitored by a diode valve voltmeter which is calibrated both in open-circuit volts and in db relative to 1 milliwatt in 600 ohms.

Illustrated descriptive leaflets of this or any other Airmec instrument will be gladly forwarded upon request.

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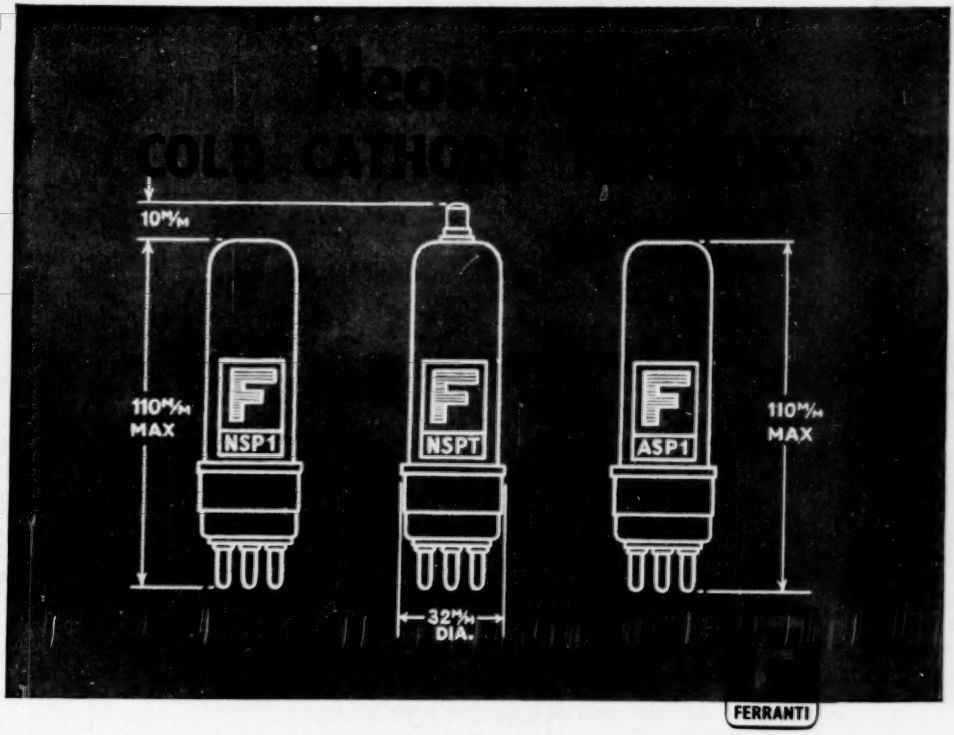
R&A



The Ferranti Neostron is a cold cathode tetrode filled with neon, designed for use as a stroboscopic light source, a flashing indicator, or an electronic relay.

The discharge in the anode is started by initiating a glow discharge between the screen and grid electrodes, the screen being at a fixed positive bias, a negative impulse being applied to the grid.

Operating Characteristics	NSP1	NSPT	ASP1
Max. Anode Voltage	400	650	400
Normal Anode Voltage	300	600	300
Mean Anode Current	40-100* mA	40-100* mA	40-100* mA
Peak Anode Current	250 Amps.	250 Amps.	250 Amps.
Max. Operating Frequency	250 c.p.s.	250 c.p.s.	300 c.p.s.
Anode Connection	in base	Top cap	in base
Gas Filling	Neon	Neon	Argon

**Dependent upon frequency of operation*

All types can be supplied with English 4 pin or American 4 pin bases.

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Output : 200/350v. 0.250mA max.
Stability : Better than 0.1%.
Output Impedance : Less than 1 ohm.
Output Ripple : Less than 2 mV. R.M.S.
Mains Supply : 200/250v. 45-60 c/s.

Stabilization and regulation are maintained for all output currents from zero to 250 mA and for mains voltage variation from + 10% to —15%.

Details of further models on application.

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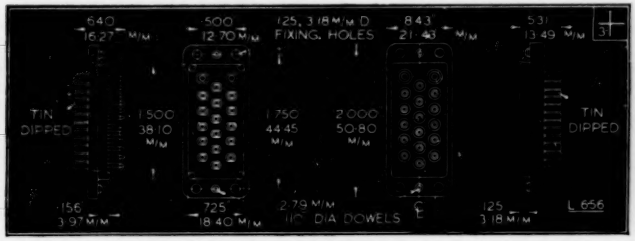
The "Belling-Lee" page for Engineers

UNITORS (Pronounced "Unite-ors")

Like any other inter-unit connector, the main purpose is to facilitate the uncoupling or replacement of a sub-assembly for servicing or replacement in event of failure.

WORKING VOLTS
500 v. Pin to Pin

The insulant is moulded from a moisture and tracking resisting, nylon-filled phenolic material. There is no metal surround, a four-hole fixing flange being incorporated in the moulding together with two locating dowels, except in the case of the four-in-line model, when two-hole fixing is provided, and no dowels.



LIST NUMBERS

L653/P & S	4 PINS
L654/P & S	8 PINS
L655/P & S	12 PINS
L656/P & S	18 PINS
L656/C Cover for above	
L657 P & S	25 PINS

A coupling comprises a block of plugs and a second block of sockets, arranged so as to be non-reversible. Round pins are employed, turned from high-grade brass, silver-plated. The normal pins carry 3 amps., but each block has two large pins or sockets to carry 10 amps. All pins are fully floating, and the method of assembly is the subject of a patent.

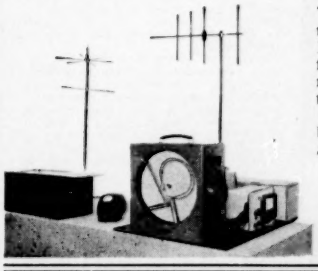
Resilient sockets are from beryllium copper and are rivetted. All contacts, plugs and sockets are numbered on the insulant face and reverse.

The distance between flanges when plugged together is 0.281". A cable cover for line connection with the 18 pole version is illustrated above, and will eventually become available for all types.

AUTOMATIC POLAR DIAGRAM PLOTTER

This apparatus has been developed by Belling & Lee Ltd. to speed up the development of television receiving aerials.

It operates at a frequency ten times greater than the ultimate design frequency and thus enables the work to be carried out on scaled-down models thereby greatly facilitating the numerous adjustments which have to be made to the element lengths and spacings to secure optimum results.



We invite you to inspect our Stand No. 137 at the Physical Society Exhibition and our Stand No. 12 at the R.E.C.M.F. Exhibition.

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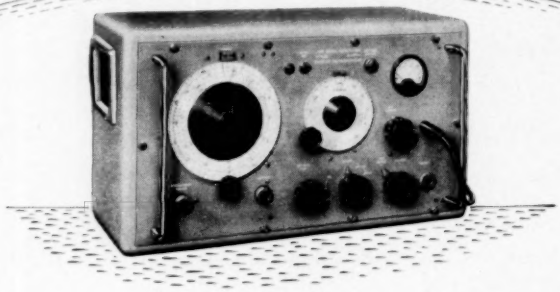
HIGH, WIDE AND HANDSOME



A wide coverage over high frequencies is of negative value unless coupled with a long, open scale for effective frequency selection. In the U.H.F. Signal Generator, TF 762C, more than five feet of continuous scale provides exceptional discrimination and accuracy over its entire range (300-600 Mc/s). Effective also are the many other features which contribute to the handsome behaviour of this Marconi instrument. With a maximum output of 1 mW into 75 ohms the level is variable by piston attenuator over 100 db. Internal pulse and 50-50 squarewave modulation at 1000 c/s are incorporated together with an externally available synchronising signal and provision for external modulation.

MARCONI INSTRUMENTS LTD St. Albans, Herts. Phone: St. Albans 6161/7

London Office: Marconi House, Strand, W.C.2. **Midland Office:** 19 The Parade, Leamington Spa. **Northern Office:** 30 Albion Street, Hull.

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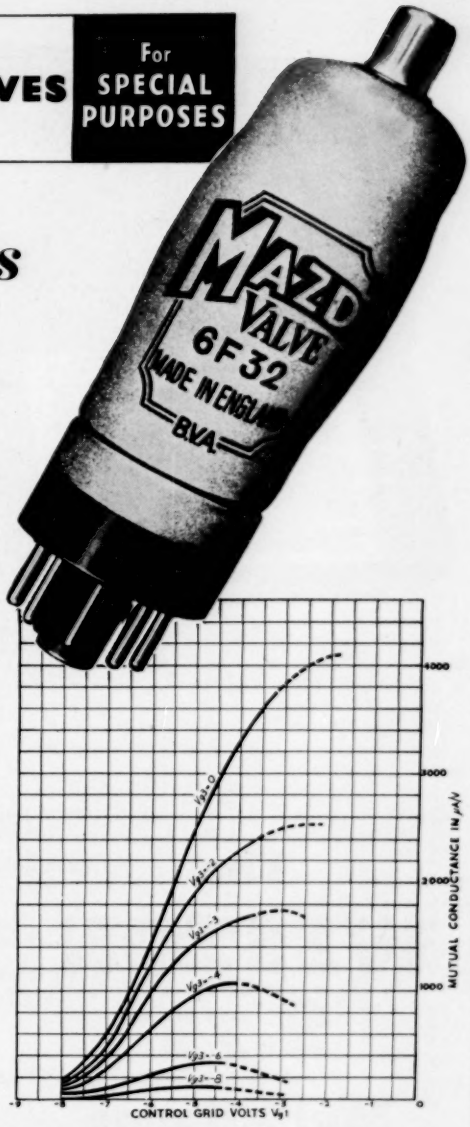

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APRIL 1951

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Published on the sixth of each month

Annual Subscription: Home and Overseas, one year £1 12s. 0d., six months 16s. : U.S.A. and Canada $5.50

Editorial, Advertising and Publishing Offices

DORSET HOUSE, STAMFORD STREET, LONDON, S.E.1

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Forward			1000V
Maximum Cathode Current. 25c/s and above.			
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Peak (for ignitor firing service)			40A
Average (for general control service)			2.5A
Average (for ignitor firing service)			1.0A
Maximum averaging time			15 secs.
Surge (maximum duration 0.1 secs.)			200A
Maximum Grid Voltage.			
Before conduction			-500V
During conduction			-10V
Maximum Grid Current.			
Average (Averaging time 15 secs.)			0.25A
Maximum Grid Resistor			0.1MΩ
Min. Cathode preheating time.			300 secs.
Condensed Mercury Temperature Limits.			40 to 80°C

CHARACTERISTICS.

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Ionisation Time (approx.)			10µ secs.
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WIRELESS ENGINEER

Vol. XXVIII APRIL 1951 No. 331

The Velocity of Light

IT is just over a hundred years since Fizeau made his classical measurement of the velocity of light by passing the beam between the teeth of a rapidly-rotating toothed wheel, and varying the speed so that, on its return from the distant mirror, the beam could be intercepted by a tooth or pass between two teeth. In 1874, Cornu repeated the measurements with greatly improved apparatus; the distance between the stations was 23 km, and 15 teeth passed by before the flash returned. The result obtained was 300,330 km/s in air, equivalent to 300,400 in vacuo. In 1834, Wheatstone had suggested the use of rotating mirrors and this was developed by Foucault in 1850; his final result was 298,000. This method was further developed in the years 1880-1885, by Michelson and Newcomb; their results, reduced to a vacuum, were respectively 299,853 and 299,860 km/s, but the fact that the latter value was given as $299,860 \pm 30$ indicates that it was necessary to take the mean of a large number of observations to obtain a reliable result.

During the last 25 years the rotating wheels and mirrors have been replaced by electrical devices. The Kerr cell was employed by Karolus and Mittelstaedt at Leipzig in 1928, and by Anderson at Harvard in 1935. If a Kerr cell is placed between two crossed Nicol prisms, it only passes light when the cell is subjected to an electric field and thus made doubly refractive. By placing the cell between the capacitor plates of a h.f. oscillatory circuit, it can be made to transmit the light twice per cycle; the returning beam can pass through a second cell excited by the same oscillatory circuit. There are various ways in which such devices can be used; in all recent applications the adjustment has not been made by the eye but by means of photo-electric tubes. During the last three or four years this method has been employed by Bergstrand in Stockholm, who claims a far greater accuracy than any other observer; he gave as the speed in vacuo $299,792{\cdot}7 \pm 0{\cdot}25$, but subsequently altered this to 299,793·1 km/sec.

A paper has recently been published by the Royal Society of Edinburgh describing experiments made by Dr. R. A. Houston of Glasgow University during the last 13 years. He replaced the Kerr cell by a piezo-electric quartz oscillator working at 115 Mc/s. The periodic electric field sets up stationary ultrasonic waves in the quartz with rarefactions and condensations and consequent variations of refractive index. When vibrating at a high harmonic frequency—Dr. Houston used the 135th harmonic—there will be a large number of parallel refractive layers, and to a beam of light passing through the quartz at right-angles to the electric field the quartz will act as an intermittent diffraction grating. This had been discovered by several physicists in 1932. As a result of the diffraction the beam from a 100 c.p. Pointolite lamp was deviated about 35 min; a reflecting mirror was placed at a distance of about 19 metres; this reflected the beam back to a lens-mirror combination, the exact position of which the observer could adjust, which returned the beam along its original path. The total length of path was thus about 4×19 metres. If, on its return, the light finds the quartz in the

diffracting condition, it will be deviated into its original path; if not, it will pass directly through the quartz without deviation and thus not be observed. The brightness of the observed light will thus increase and decrease as the length of path is increased. For maximum brightness the time occupied by the double journey must correspond to an exact multiple of the time between two successive gratings; that is, half the electrical period. The quartz was placed between the capacitor plates of a push-pull electric oscillator, the frequency of which could be determined by means of multivibrators based on the frequency of the Droitwich carrier wave. The final result for air was $299{,}698 \pm 9$ km/s which, using figures given by Birge, is equivalent to $299{,}775 \pm 9$ for a vacuum, but which becomes $299{,}782 \pm 9$ if more recent correcting data determined at the National Physical Laboratory are employed.

Determinations of the velocity of electromagnetic waves in vacuo have recently been made at the N.P.L. by Essen and Gordon-Smith using cavity resonators of very accurately known dimensions. Although the wavelength employed was about 40,000 times that of light, the results indicate that the velocity is the same. Their final result is $299{,}792{\cdot}5 \pm 3$; this is determined for a vacuum and therefore needs no correction. It depends upon the accurate determination of the dimensions of the cavity resonator, constant temperature and the absence of surface films. Dr. Bol of Stanford University has also used a cavity resonator and gives as a provisional figure $299{,}789{\cdot}3 \pm 0{\cdot}4$. In *Nature* of 17th February, p. 258, Dr. Essen gives the following as the most recent determinations:—

Bergstrand(optical)	$299{,}793{\cdot}1 \pm 0{\cdot}26$
Aslaskon (radar)	$792 \pm 2{\cdot}4$
Essen (cavity resonator)	$792{\cdot}5 \pm 3$
Bol (cavity resonator)	$789{\cdot}3 \pm 0{\cdot}4$

Dr. Essen suggests that the value 299,790 km/s be adopted until still more accurate measurements have been made.

When a measurement of the velocity in air has been made, a number of corrections have to be applied to obtain the equivalent velocity in a vacuum. These were discussed in detail by Barrell and Sears in 1939 (*Phil. Trans. Roy. Soc.*, Vol. 238, p. 1), and their final formula for the refractive index n of the air was as follows:—

$$(n-1)10^6 = \left[0{\cdot}378125 + \frac{0{\cdot}0021414}{\lambda^2} + \frac{0{\cdot}00001793}{\lambda^4}\right] + p\left[\frac{1 + (1{\cdot}049 - 0{\cdot}0157t)p \times 10^{-6}}{1 + 0{\cdot}003661t}\right] - \frac{f}{1 + 0{\cdot}003661t}\left[0{\cdot}0624 - \frac{0{\cdot}000680}{\lambda^2}\right]$$

in which p is the barometric pressure in mm, f the water vapour pressure in mm, λ the wavelength in microns and t the temperature in degrees Centigrade.

This applies to standard air with 0·03% by volume of CO_2.

If we put $p = 760$, $f = 10$ and $t = 22°C$, then the formula gives the following values for the refractive index:—

If $\lambda = 0{\cdot}2$ micron	$n = 1{\cdot}0003112$
0·3 micron	1·0002839
0·4 micron	1·0002755
0·5 micron	1·0002717
0·8 micron	1·0002677
1·0 micron	1·0002670

For visible light λ lies between 0·4 and 0·8. The reciprocal of these values gives the ratio of the velocity in air to that in a vacuum; for $\lambda = 0{\cdot}4$, $v_a/v_v = 0{\cdot}9997245$ and for $\lambda = 0{\cdot}8$, $v_a/v_v = 0{\cdot}9997323$ a difference of about 1 part in 10^5. These are phase velocities, and the fact that the phase velocity varies with λ shows that the group velocity will be less than the phase velocity. To find the group velocity we use the formula*

$$v_g = v_a - \lambda \frac{dv_a}{d\lambda}$$

or

$$\frac{v_g}{v_v} = \frac{v_a}{v_v} - \frac{\lambda}{\delta\lambda} \cdot \delta\left(\frac{v_a}{v_v}\right)$$

$$= 0{\cdot}999728 - \frac{0{\cdot}6}{0{\cdot}4}(0{\cdot}0000078)$$

$$= 0{\cdot}999716$$

This is only approximate as it assumes a linear variation from $\lambda = 0{\cdot}4$ to 0·8 about the mean 0·6 but it shows that the group velocity is less than the phase velocity by about 1 part in 10^5 and less than the vacuum velocity by about 28 parts in 10^5; i.e., 84 parts in 300,000. Hence, if the velocity in a vacuum is 299,790 km/s the measured velocity in air under the assumed conditions would be 299,706 km/s if the measurements were correctly made.

It must be considered very satisfactory that the four experimental results given above, obtained by such different methods and for such different frequencies, have an overall difference of less than 4 parts in 300,000.

G. W. O. H.

* See *Wireless Engineer*, December 1943, p. 577.

TRANSITION OF AN ECCLES-JORDAN CIRCUIT

By J. R. Tillman, Ph.D., A.R.C.S.

SUMMARY.—The Eccles-Jordan circuit will undergo a transition from one stable state to the other when a triggering signal causes the loop gain of the circuit to fail to satisfy the Nyquist criterion for stability of an amplifier. Analyses show how the speed of transition depends on the circuit parameters, one of which—the loop gain—must change before a transition can be completed. They deal only with the simpler circuits. The step-by-step method, which provides an alternative way of calculating a transition, is less limited in scope, but its accuracy is not easily defined. Comparisons of the results of analyses with results obtained by step-by-step computation illustrate the accuracy of the step-by-step method.

The full action of the triggering pulse and the disadvantage of using too long a pulse are well shown by step-by-step calculations. Some practical high-speed circuits undergo transitions in only a few tens of milli-microseconds and, not surprisingly, can be triggered by pulses lasting only 20 milli-microseconds.

1. Introduction

AUTHORS have often broadly described the operation of valve circuits having two stable or quasi-stable states (e.g., pulse triggers and free-running multivibrators); some have derived expressions for the duration t_q of any quasi-stable state involved, e.g., in multivibrator (astable) and in flip-flop (monostable) circuits. They have usually implied that the transition from one stable or quasi-stable state to the other takes place instantaneously once the circuit reaches the critical point in the transition at which positive feedback can take control. Clearly, however, some time t_c must be taken up in charging the inevitable shunt capacitances of those parts of the circuit whose energizations determine the state of the circuit, even during the period when positive feedback plays the all important part. Moreover t_c is only a part of the total time of transition of the circuit; a time* t_a is taken to bring the circuit to the critical point and another t_b, is taken for stability to be substantially reached after positive feedback has lost control.

In the past there has been justification for ignoring t_c. In circuits with two stable states (which therefore need a fresh triggering pulse to effect each change of state) few applications until recently have involved gaps between consecutive triggering pulses of less than a microsecond or two, whereas designers have found little difficulty in reducing t_c to a small fraction of a microsecond, and even $t_a + t_c + t_b$ to less than 1 μs.

However, the wish to increase the speed of operation of some parts of electronic computers must be expected; $t_a + t_c + t_b$ may well have to be much reduced particularly in two-position (bistable) trigger circuits, among which the original, the Eccles-Jordan, is still prominent. Now the relationships between the circuit parameters and the size and shape of the triggering pulse on the one hand and t_a and, to a lesser extent perhaps, t_b on the other, are not difficult to seek and are calculable. The reduction of these two times is largely a matter of engineering; it calls for small tolerances on resistor values, valve characteristics and power-supply voltages and for steep-fronted triggering pulses, and as such does not concern this paper. (The optimum magnitude and duration of the triggering pulse is a more involved problem briefly discussed later.)

The period t_c is less well understood, but some efforts have been made to find it analytically. Thus D. Sayre[1] has made an analysis of the transition between states of an astable multivibrator (the conventional multivibrator with capacitive coupling between the anode A of one valve and the grid G of the other and vice versa). He took into account the capacitance between A and G of each of his triode valves (though ignoring some Miller effects), but gave $\frac{dI_a}{dV_g}$ $(= g)$ one of two values only—zero, when the potential of G is beyond cut-off, and a constant finite value when it is not. His calculations lead to expressions for voltages as power series of time t. He comments that "exact analysis . . . is practically impossible," but finds that "experimental rise times agree very well with these calculated ones."

E. M. Williams, D. F. Aldrich and J. B. Woodford[2] have also analyzed the conventional multivibrator, once more giving their valves only one value of g other than zero. They draw several conclusions from the equations derived; e.g., that the shape of the voltage in the transition interval should be independent of the triggering voltage. They find fair agreement between their analysis and practice. It was at first sight surprising to

* t_a and t_b may form part of, or exist concurrently with, t_q in multivibrators. In synchronized astable multivibrators t_a, at least, is a function of the synchronizing pulse.

MS accepted by the Editor, May 1950

find their statement "There seems to be little correlation between transition time and the time constants of the load resistances (in parallel with dynamic plate resistance) in combination with shunt capacity although this has been suggested as a major factor by Kiebert and Inglis[3] and others. The shunt capacity is indeed of major importance but the load resistance . . . (is not) . . . ," though they subsequently put forward strong arguments in support. Perhaps it is not unfair to summarize their argument by saying that if an anode load is increased, the total anode movement and the time taken to perform it will increase, but that the time taken to move a few volts (e.g., the grid base of a small h.f. pentode) need take no longer. They favour graphical methods (based on step-by-step calculations) for determining the performance of any practical unit, sound advice despite all analyses so far. Finally they report failure to simplify sufficiently the analysis of the Eccles-Jordan circuit to achieve worthwhile results, although the graphical method presents little additional complication.

The present paper will, however, concern itself solely with the Eccles-Jordan circuit ; even a simple attack on it leads to points of interest.

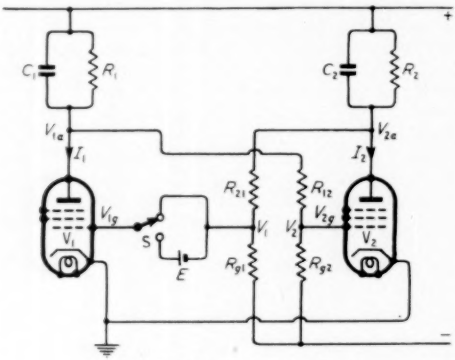

Fig. 1. *The Eccles-Jordan circuit.*

2. Circuit Investigated

Fig. 1 shows the circuit investigated. Pentodes are used in order that the capacitance between control grid and anode shall be negligible. The means of triggering is shown as the insertion of a battery E in the lead to one grid ; clearly there are equivalent methods of achieving the purpose of changing the potential of one grid suddenly. C_1 and C_2 represent the total shunt capacitance at each anode. In practice each control grid may have a significant earth capacitance ; but by bridging R_{21} and R_{12} by suitable capacitances, the potential dividers R_{12} and R_{g2} and R_{21} and R_{g1} can be kept free of attenuation distortion and the net capacitances appearing at the anodes taken account of in determining C_1 and C_2. $R_{12} + R_{g2}$ and $R_{21} + R_{g1}$ are assumed to be very much larger than R_1 and R_2 respectively.

The time constants of the anode circuits, C_1R_1 and C_2R_2, figure prominently in the analyses and are designated t_1 and t_2 ; in practice they are often only a few tens of milli-microseconds.

Attention must be given to several points, including those indicated earlier, if fast and consistent operation of the circuit is to be assured. Thus the potential dividers should be so chosen as to ensure that for one stable state of the circuit V_1 is at about cut-off potential and V_2 at about cathode potential and for the other stable state the reverse ; but as will be shown, practical considerations impose some restrictions.

Positive feedback round the loop $G(V_1)$–$A(V_1)$–$G(V_2)$–$A(V_2)$–$G(V_1)$ can control the movements of the currents and voltages of the circuit. When the loop gain, plotted on a Nyquist diagram, includes the point $1\angle 0$ (unity gain and zero phase shift)† it can cause a transition from one stable state to the other.

Triggering, to be effective, need only ensure that positive feedback can take full control. The triggering voltage can, however, be so large or last so long that the potential of the anode of one valve changes by substantially the ultimate amount before the anode potential of the other valve has changed very much. The transition can then take place without positive feedback playing an important role ; t_c loses importance to t_b and the transition ceases to be interesting theoretically. In the analyses that follow in Section 3, triggering never exceeds that which allows positive feedback to assume importance.

Throughout, the circuit is assumed to be free from noise.

3. Analysis of the Circuit

3.1. *Following the operation of S.*

3.1.1. *Linear valve characteristics.*

The authors of the two articles[1,2] on multivibrators assumed a linear relationship between I_a and V_g. It is instructive, as a first step, to tackle the Eccles-Jordan circuit on the same basis.

The analysis must deduce the changes of the potentials of the valve electrodes with time. Transitions can be considered only if some limits are placed on the ranges of I_a and V_g over which linearity holds. If the ranges terminate abruptly

† Mr. Hansford and I have confirmed experimentally that this criterion (never, as far as we know, previously postulated explicitly for valve switches) is the important one, at least in circuits for which the maximum loop gain occurs at zero frequency (e.g., that of Fig. 1), in circuits with 'speed-up' capacitors across either or both R_{12} and R_{21} where the maximum gain occurs at some frequency other than zero and in circuits in which the anode load of, say, V_1 is augmented by a parallel-tuned circuit, resonating at some frequency well below $1/C_1R_1$.

(i.e., g immediately goes to zero) the extension of the analysis needed to include a transition is small; if g changes smoothly outside the ranges, the analysis becomes complex.

Suppose first that $C_1 \gg C_2$; the latter can then be ignored.

Let the initial values of V_{1a} and V_{2a} be V_{1a0} and V_{2a0}, $R_{g2} = \rho_1(R_{12} + R_{g2})$ and $R_{g1} = \rho_2(R_{21} + R_{g1})$, $\frac{dI_a}{dV_{1g}} = g_1$ and $\frac{dI_2}{dV_{2g}} = g_2$. Let the switch S, introducing an e.m.f., E, be operated at time $t = 0$.

Then

$$\left.\begin{aligned} I_1 &= I_{10} + g_1(V_1 + E) \\ &\quad \text{where } R_1 I_{10} = -V_{1a0} \\ I_2 &= I_{20} + g_2 V_2 \\ &\quad \text{where } R_2 I_{20} = -V_{2a0} \\ V_1 &= \rho_2(V_{2a} - V_{2a0}) \\ V_2 &= \rho_1(V_{1a} - V_{1a0}) \\ V_{2a} &= -R_2 I_2 \quad \text{and} \\ \frac{dV_{1a}}{dt} &= -(R_1 I_1 + V_{1a})/C_1 R_1 \end{aligned}\right\} \quad (1)$$

These equations enable one connecting only V_{1a} and t to be found: it is

$$\frac{dV_{1a}}{dt} = \frac{1}{C_1 R_1}\{(M-1)(V_{1a} - V_{1a0}) - g_1 R_1 E\} \quad (2)$$

M being the loop gain at zero frequency, $\rho_1\rho_2 R_1 R_2 g_1 g_2$.

Putting $v_1 = V_{1a} - V_{1a0}$ and solving (2)

$$v_1 = \frac{g_1 R_1 E}{(M-1)}\{1 - e^{(M-1)t/C_1R_1}\} \quad .. \quad (3)$$

remembering that $v_1 = 0$ at $t = 0$.

M clearly has a big influence on the relationship between v_1 and t. If $M < 1$, the index is negative; the motion of v_1 is arrested with time, v_1 ultimately coming to rest at $g_1 R_1 E/(M-1)$. $|v_1|_t = \infty$ is always more than $g_1 R_1 E$ unless $M = 0$, when it must obviously be $g_1 R_1 E$.

As the loop gain $M \to 1$,

$$v_1 \to -\frac{g_1 E t}{C_1}\left[1 + \frac{(M-1)t}{2C_1R_1} \ldots\ldots\right];$$

when $M = 1$, $v_1 = -\frac{g_1 E t}{C_1}$; i.e., v_1 changes steadily with time (indefinitely, if the valve characteristics allow!) at the rate of $-\frac{g_1 E}{C_1}$ volts/sec, the rate at which a current of $-g_1 E$ charges a capacitance C_1. It is significant that this rate is independent of R_1, but R_1 must play its part in satisfying the relationship $\rho_1\rho_2 R_1 R_2 g_1 g_2 = 1$.

If $M > 1$, v_1 becomes more and more negative with time at an ever-increasing rate. (In practice the circuit would be unstable even before S was operated, noise initiating an ever-increasing movement of electrode potentials.)

Because movements of V_{1a} are instantly reflected in movements of V_{2a}, expressions for V_{2a} follow without difficulty and call for no comment.

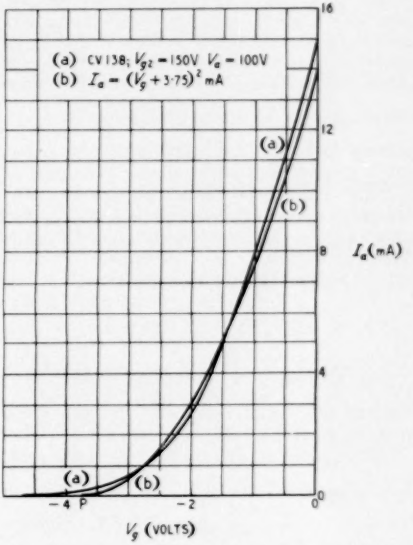

Fig. 2. *Comparison of I_a/V_g relationship of CV138 with parabola.*

Now let C_2 have a significant value. The equation $V_{2a} = -R_2 I_2$ of set (1) now becomes $\frac{dV_{2a}}{dt} = -(R_2 I_2 + V_{2a})/C_2 R_2$; the others are unchanged. The new set produces the equation for v_1

$$\frac{d^2v_1}{dt^2} + \left(\frac{1}{C_1R_1} + \frac{1}{C_2R_2}\right)\frac{dv_1}{dt} + \left(\frac{1-M}{C_1C_2R_1R_2}\right)v_1 = -\frac{g_1R_1E}{C_1C_2R_1R_2} \quad .. \quad .. \quad .. \quad .. \quad (4)$$

whose solution can be obtained by conventional means. It is simplified if the two time constants C_1R_1 and C_2R_2 are equal, as is often so in practice. Let each time constant be t_1. Then equation (4) reduces to

$$\frac{d^2v_1}{dt^2} + \frac{2}{t_1}\frac{dv_1}{dt} + \frac{(1-M)v_1}{t_1^2} = -\frac{g_1R_1E}{t_1^2}$$

whence

$$v_1 = Ae^{-(1-\sqrt{M})t/t_1} + Be^{-(1+\sqrt{M})t/t_1} - g_1R_1E/(1-M) \quad .. \quad .. \quad .. \quad (5)$$

But $v_1 = 0$ when $t = 0$ and clearly $\left(\frac{dv_1}{dt}\right)_{t=0} = -\frac{g_1R_1E}{t_1}$ (the same as that calculated when C_2 is absent, independently of M). A and B are therefore determinate; equation (5) becomes

$$v_1 = \frac{g_1R_1E}{2(1-M)}\left[(1+\sqrt{M})e^{t\sqrt{M}-1)t/t_1} + (1-\sqrt{M})e^{-(\sqrt{M}+1)t/t_1} - 2\right] \quad .. \quad (6)$$

If $M < 1$, both exponential terms have negative indices and $\frac{dv_1}{dt}$, after beginning as $-\frac{g_1R_1E}{t_1}$ slows up and eventually becomes zero, v_1 having become $-\frac{g_1R_1E}{(1-M)}$.

If $M > 1$, one exponential term has a positive index and v_1 ultimately changes at an ever increasing rate.

If $M = 1$

$$v_1 = -\frac{g_1R_1E}{4}\left(1-e^{-2t/t_1}+\frac{2t}{t_1}\right)$$

so that ultimately v_1 moves as $-\frac{g_1R_1Et}{2t_1}$; i.e., one half its initial rate and one half the rate applying when $C_2 = 0$.

The change of voltage at the anode of V_2, $v_2 = V_{2a} - V_{2a0}$, is simply found; it is

$$v_2 = -\frac{E\sqrt{M}}{2(1-M)\rho_2}\left[(\sqrt{M}+1)e^{t\sqrt{M}-1)t/t_1} + (\sqrt{M}-1)e^{-(\sqrt{M}+1)t/t_1} - 2\sqrt{M}\right] \quad .. \quad (7)$$

Qualitatively, v_2, though moving in the opposite direction, behaves as does v_1 for $M < 1$, $M = 1$ and $M > 1$ except that $\frac{dv_2}{dt}$ is zero at $t = 0$. Quantitatively, and when $M = 1$,

$$v_2 = \frac{E}{4\rho_2}\left[\frac{2t}{t_1} + e^{-2t/t_1} - 1\right]$$

so that ultimately v_2 moves as $\frac{Et}{2\rho_2t_1}$, which, for a circuit in which $g_1R_1\rho_2 = g_2R_2\rho_1 = \sqrt{M} = 1$, is as $\frac{g_1R_1Et}{2t_1}$; i.e., is as $-v_1$.

Fig. 3, included primarily to illustrate other points, shows the relationships between v_1 and v_2, and t, when $g_1R_1\rho_2 = g_2R_2\rho_1 = \sqrt{M} = 1{\cdot}5$.

If $M = 1$, the calculations involved when $R_1C_1 \neq R_2C_2$ are much simplified and worthwhile pursuing in order to calculate $\frac{dv_1}{dt}$. Let $C_1R_1 = t_1$ and $C_2R_2 = t_2$.

Then $\frac{d^2v_1}{dt^2} + \left(\frac{1}{t_1}+\frac{1}{t_2}\right)\frac{dv_1}{dt} = -\frac{g_1R_1E}{t_1t_2}$

and, allowing for the conditions at $t = 0$,

$$v_1 = -\frac{g_1R_1E}{(t_1+t_2)}\left[t + \frac{t^2{}_2}{(t_1+t_2)} - \frac{t^2{}_2}{(t_1+t_2)}e^{-t\left(\frac{1}{t_1}+\frac{1}{t_2}\right)}\right].$$

Hence for values of $t \gg t_1$ and t_2, v_1 changes as $-\frac{g_1R_1Et}{t_1+t_2}$, although when $t \ll t_1$ and t_2 it changes as $-\frac{g_1R_1Et}{t_1}$.

If g_1 (or g_2) goes to zero at some value of V_{1a} (or V_{2g}), the calculation of the time of a transition involves finding the value of t which makes v_2 (or v_1) consistent with that value of V_{1g} (or V_{2g}). The absence of positive feedback when g_1 (or g_2) has fallen to zero simplifies the calculation of subsequent changes of v_1 and v_2.

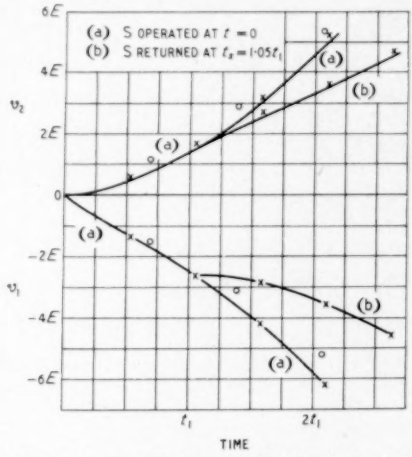

Fig. 3. *Illustrating the accuracy of the step-by-step method when the valve characteristic is linear and* $R_1C_1 = R_2C_2$. *Curves by rigid analysis. Points obtained by step-by-step method, using* $t_2 = 0{\cdot}69\ t_1$, *shown* o; *every fifth point obtained by the method, using* $t_2 = 0{\cdot}105\ t_1$, *shown* x.

3.1.2 *Non-linear valve characteristics*

An assumption that $\frac{dI_a}{dV_g} = g$ is constant (but $\neq 0$) over a limited range of V_g and zero outside the range is often reasonable enough if the transition of the valve switch involves much of the range (or ranges) where $g = 0$. For then much of the time of operation may be taken up with bringing one or both control grids to the point(s) where g assumes its finite value, and the calculation of the total time of operation need incur little error by ignoring the practical changes of g with

V_g when g is not zero. If, on the other hand, the region where $g = 0$ is not to be entered by the control grids of either V_1 or V_2, more consideration ought to be given to the exact relationship between I_a and V_g.

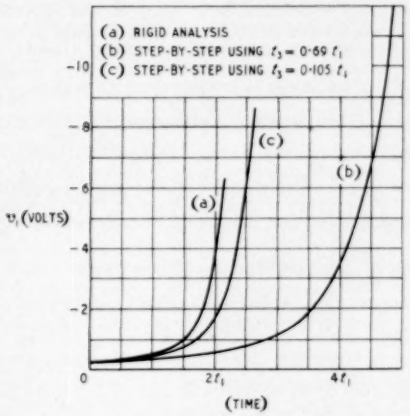

Fig. 4. *Illustrating the accuracy of the step-by-step method when the valve characteristic is parabolic and $C_2 = 0$.*

I_a can be set down as a power series in V_g; only a few terms are needed to ensure a good fit in practice; but a power series extending only to V_g^3 makes analysis of the transition very complex. The relationship $I_a = k(V_g - V_{g0})^2$ is a compromise between undue complexity and undue variance from practice. (Fig. 2 compares the characteristic of a CV138 with a parabola). If $C_2 = 0$, equation (1) becomes

$$\left.\begin{aligned} I_1 &= k_1(V_1 + V_{10} + E)^2, \\ I_2 &= k_2(V_2 + V_{20})^2 \text{ where } V_{10} \text{ and } V_{20} \text{ are positive quantities measured relative to the points where } I_1 = 0 \text{ and } I_2 = 0 \text{ respectively.} \\ V_1 &= \rho_2(V_{2a} - V_{2a0}), \\ V_2 &= \rho_1(V_{1a} - V_{1a0}) = \rho_1 v_1 \\ V_{2a} &= -I_2R_2 \text{ and} \\ \frac{dv_1}{dt} &= -(I_1R_1 + V_{1a})/C_1R_1 \end{aligned}\right\} \quad \ldots \quad (8)$$

Suppose $\rho_1 = \rho_2 (= \rho)$, a common practical condition, and that at $t = 0$ the loop gain at zero frequency, $4k_1k_2\rho^2R_1R_2V_{10}.V_{20}$, is unity.

If $E = 0$, a stage in the solution of (8) is

$$\frac{dv_1}{dt} = -\frac{v_1^2\rho}{t_1(V_{10}.V_{20})^{3/2}} \left[\frac{\rho^2 v_1^2}{8} + \frac{\rho v_1 V_{20}}{2} + \frac{V_{20}^2 - V_{10}^{3/2}.V_{20}^{1/2}}{2}\right] \quad (9)$$

i.e., $\left(\frac{dv_1}{dt}\right)_{v_1=0} = 0$. If, however, v_1 is given a small displacement, then $\frac{dv_1}{dt} \propto -v_1^2(V_{20}^2 - V_{10}^{3/2}.V_{20}^{1/2})$ initially. Then for $V_{20} > V_{10}$, $\frac{dv_1}{dt}$ is negative, so that if the displacement assumed is positive, the circuit moves towards the condition $v_1 = 0$; i.e., back to the starting state. If the displacement is negative, however, the circuit moves away from $v_1 = 0$ at, for some time, an ever increasing rate, effecting a transition. Equally if $V_{10} > V_{20}$, $\frac{dv_1}{dt}$ is positive and a positive displacement is required to effect a transition. In other words, if V_1 is the valve which is the more nearly turned off ($V_{10} < V_{20}$) its anode potential must be moved negatively in order that the circuit shall change state (and vice versa)—the expected qualitative conclusion.

If $E \neq 0$, and only the initial changes of v_1 are required, equation (8) yields

$$\frac{dv_1}{dt} = -\frac{k_1R_1(2V_{10}E + E^2)}{t_1} \quad \ldots \quad \ldots \quad (10)$$

and since $\left(\frac{dI_1}{dv_{1g}}\right)_{t=0} = g_{10} = 2k_1V_{10}$, if $E \ll V_{10}$, $\left(\frac{dv_1}{dt}\right)_{t=0} = -\frac{g_{10}R_1E}{t_1}$ as would be expected.

If $E \neq 0$, $\frac{dv_1}{dt}$, when v_1 has attained a value comparable with E, is given by an equation which, though involving terms additional to those given in (9) and (10), is of practical value.

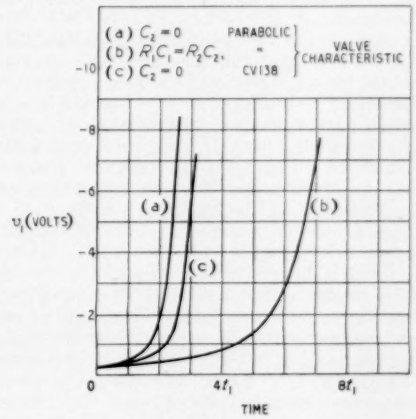

Fig. 5. *Some results obtained by the step-by-step method using $t_2 = 0{\cdot}105\ t_1$.*

Equation (9) can be integrated for t in terms of v_1 without difficulty, and the time taken for v_1 to change from a first value v_{11} to a second value v_{12} can be calculated. (The time taken to reach any finite value of v_1, from $v_1 = 0$ is infinite

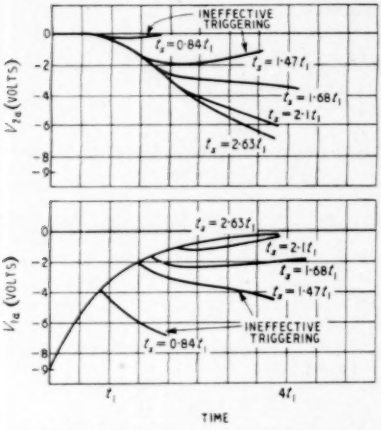

Fig. 6. *Influence of the length t_s of the triggering pulse. Negative pulse applied to shut V_1.*

unless an initial impulse is given.) If V_1 is the valve more nearly turned off initially, the time taken for I_2 to be reduced to zero (i.e., for $V_2 + V_{20}$ to become zero) is given by the time taken for v_1 to reach the value $-\dfrac{V_{20}}{\rho}$ from some other value v_{11}. For more negative values of V_2, I_2 should clearly be given the value of zero (i.e., the characteristic of the valve to the left of the point P in Fig. 2 is not the other half of the parabola but is the V_g axis).

If a circuit is set up with its loop gain at unity, the transition time can therefore be calculated, provided E or the initial small disturbance of V_{1a} is known.

When $C_2 \neq 0$, the expression relating t and v_1 is very complex and of little practical value. Nonetheless $C_1 \approx C_2$ is a common practical occurrence. In order that the influence of C_2 should be clear, the analysis must make way, in Section 4, for the empirical step-by-step method.

3.2. *Following a subsequent return of S.*

If S returns after a time t_s, the subsequent behaviour of the circuit can be gauged in part from considerations of the potentials $(V_1)_{t=t_s} = V_{1s} = \rho_2(v_2)_{t=t_s} = \rho_2 v_{2s}$ and $(V_2)_{t=t_s} = V_{2s} = \rho_1(v_1)_{t=t_s} = \rho_1 v_{1s}$. Thus although V_{1g}, while having the contributions E and V_{1s}, causes charging of C_1 in the direction originally fixed by the polarity of E (except that charging ultimately ceases if $M < 1$), the loss of E may mean that V_{1g} is insufficient to continue charging in this sense, whereupon $\dfrac{dV_{1a}}{dt}$ is reversed, at least temporarily. On the other hand, V_{2g} suffers no change in value at $t = t_s$, so that, for the time being, C_2 continues to charge in the direction applying just before $t = t_s$. Illustrations of these behaviours will be found in Figs. 3, 6 and 7.

If, immediately following the return of S, $\dfrac{dV_{1a}}{dt}$ and $\dfrac{dV_{2a}}{dt}$ remain of opposite signs, the subsequent behaviour of the circuit is usually clear. If, however, $\dfrac{dV_{1a}}{dt}$ changes sign at the closure, the behaviour is less obvious. Usually either $\dfrac{dV_{1a}}{dt}$ or $\dfrac{dV_{2a}}{dt}$ subsequently changes sign. If $\dfrac{dV_{1a}}{dt}$ changes sign again the circuit moves in the direction it did during the period $t = 0$ to $t = t_s$ and a transition takes place. If $\dfrac{dV_{2a}}{dt}$ changes sign the circuit seeks to return to the conditions applying at $t = 0$. Exceptionally neither may subsequently change sign before reducing to zero; either v_{1s} may much exceed the value of v_1 proper to a transition (see, for example, the curve for $t_s = 2{\cdot}63t_1$ in Fig. 7) or M may have and retain the theoretically interesting but impracticable value of unity.

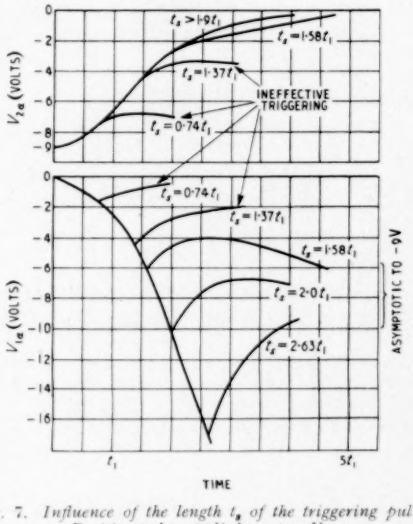

Fig. 7. *Influence of the length t_s of the triggering pulse Positive pulse applied to open V_1.*

Some of the analysis of Section 3.1 can be usefully extended to find the behaviour at times after t_s. That in which the valve characteristics are non-linear cannot simply be extended; resort must then again be made to the step-by-step method. When the valve characteristics are linear, the analysis can conveniently continue to distinguish between (*a*) $C_2 = 0$ and (*b*) $R_1C_1 = R_2C_2$ but cannot simply deal with $R_1C_1 \neq R_2C_2 \neq 0$.

(*a*) When $C_2 = 0$, and at the return of S, $\rho_2 v_{2s} + \frac{v_{1s}}{g_1 R_1}$ (the voltage by which $\rho_2 v_{2s}$ exceeds $-\frac{v_{1s}}{g_1 R_1}$ and hence V_{1g} exceeds that necessary to sustain the charge on C_1) is $E(e^{(M-1)t_s/t_1} - 1)$; it can be substituted for E in the earlier analysis [Section 3.1.1] as if it were a triggering voltage. Consequently, if $M < 1$ the total further movement of V_{1a} is, from equation (3), $\frac{g_1 R_1 E}{(1-M)}\left[1 - e^{-(1-M)t_s/t_1}\right]$, which exactly cancels the movement prior to t_s.

If $M = 1$, there is no further movement after the return of S.

If $M > 1$, $E\left[e^{(M-1)t_s/t_1} - 1\right]$ is positive and V_{1a} continues in the direction it was set by E at the operation of S.

(*b*) When $C_1R_1 = C_2R_2$ equations (6) and (7) give v_1 and v_2 respectively at $t = t_s$. When M has the special value of unity, $\rho_2 v_{2s} + v_{1s}/g_1R_1 =$ say, $E_{1s} = -\frac{E}{2}\left[1 - e^{-2t_s/t_1}\right]$ which has the polarity of $-E$. But $\rho_1 v_{1s} + v_{2s}/g_2R_2 =$ say, $E_{2s} = -\frac{E}{2g_2R_2\rho_2}\left[1 - e^{-2t_s/t_1}\right]$ which also has the polarity of $-E$. E_{1s} and E_{2s} therefore oppose one another in their action on the circuit, all of whose electrode potentials ultimately come to rest at some value other than those applying before S was operated, a behaviour most clearly seen if $g_1R_1\rho_1$ and $g_2R_2\rho_2$ are each unity.

When $M \neq 1$, E_{1s} and E_{2s} can once again be calculated. The motion of V_{1a} subsequent to the return of S, v_{s1}, is then given by the equations $\frac{d^2v_{s1}}{dt^2} + \frac{2}{t_1}\frac{dv_{s1}}{dt} - \frac{(1-M)v_{s1}}{t_1^2} = -\frac{g_1R_1}{t_1^2}$ $(E_{1s} - \rho_2g_2R_2E_{2s})$, $v_{s1} = 0$ at t (now measured from t_s) $= 0$ and $\left(\frac{dv_{s1}}{dt}\right)_{t=0} = -\frac{g_1R_1E_{1s}}{t_1}$, so that if $\rho_1g_1R_1 = \rho_2g_2R_2 = \sqrt{M}$

$$v_{s1} = \frac{-\sqrt{M}}{2\rho_1(M-1)}\left[(\sqrt{M}+1)(E_{1s}-E_{2s})e^{(\sqrt{M}-1)t/t_1} - (\sqrt{M}-1)(E_{1s}+E_{2s})e^{-(\sqrt{M}+1)t/t_1} - 2(E_{1s}-\sqrt{M}E_{2s})\right] \quad (11)$$

Similarly

$$v_{s2} = \frac{-\sqrt{M}}{2\rho_2(M-1)}\left[(\sqrt{M}+1)(E_{2s}-E_{1s})e^{(\sqrt{M}-1)t/t_1} - (\sqrt{M}-1)(E_{2s}+E_{1s})e^{-(\sqrt{M}+1)t/t_1} - 2(E_{2s}-\sqrt{M}E_{1s})\right] \quad (12)$$

An example of the use of these two equations is given later.

4. Step-by-step Method

The step-by-step method is not difficult to use. The influence of the triggering pulse E direct or indirect, on all the valve currents and electrode potentials is calculated over a first period of time t_3 (preferably so related to t_1 as to simplify the consequent arithmetic). The potential of the electrode originally displaced by E is now found to be further displaced, by δ_1. The new total displacement $E + \delta_1$ is now assumed to apply for a second period of t_3 and so on. If the behaviour of a circuit not being stimulated by an externally applied pulse is sought, a small displacement δ_0 of the potential of one of the electrodes must be assumed. Clearly the method will give full and accurate information if δ_0 and, more particularly, t_3 are made very small.

The calculations can be very simple if $R_1C_1 \gg R_2C_2$; first V_{2a} can be assumed to respond instantly to changes of V_{2g} (and hence to those of V_{1a}) the second, the value of the current $(I_1)_{n+1}$ charging C_1 and changing V_{1a} from $(V_{1a})_n$ to $(V_{1a})_{n+1}$ during the $(n+1)$th period can, with some confidence, be taken as that flowing at the end of the nth period, whose calculation will just have been made. But the movements of the electrode potentials will appear to proceed more slowly the larger the value of t_3.

When R_1C_1 and R_2C_2 are comparable, however, the choice of $(I_1)_{n+1}$ and $(I_2)_{n+1}$ is more open. Each may be taken as that flowing in the relevant valve at the end of the nth period, but the movements of the electrodes will appear to proceed even more slowly the larger is t_3. Improved accuracy is obtained if mean values of the currents flowing during the $(n+1)$th period are estimated by extrapolation from the values calculated for earlier periods, but the arithmetic increases. Thirdly, $(I_1)_{n+1}$ can be taken as the current flowing at the *beginning* of the $(n+1)$th period and $(I_2)_{n+1}$ as the current flowing at the *end* of the period; no extrapolation or extra work is needed to find this value of $(I_2)_{n+1}$ which becomes known as soon as the effect of $(I_1)_{n+1}$ on V_{1a} and hence V_{2g} is calculated, as it must be. At first sight the simplification involved in the third choice of

currents would seem to lead to cumulative exaggeration of the movement of V_{2a} and an underestimate of that of V_{1a}; but closer inspection shows that the unequal treatment obviously applying during the first few periods of t_3 acts to decrease subsequent inequalities so much that over any number of periods the relative timing error of V_{1a} and V_{2a} appears to be much less than t_3. The third choice has accordingly been used in all curves shown subsequently where $C_1R_1 = C_2R_2$.

Figs. 3 and 4 compare results obtained by the step-by-step method (using two separate values* of t_3, $0{\cdot}105\ t_1$ and $0{\cdot}69\ t_1$) with those obtained by analysis. For Fig. 3 the valve characteristics are linear, with $R_1C_1 = R_2C_2$, $g_1R_1 = g_2R_2 = 3$, $\rho_1 = \rho_2 = 1/2$ and therefore $M = 2{\cdot}25$. S introduced a voltage E at time $t = 0$, and for curves and points (b) removed it again at time $t = 1{\cdot}05t_1$. Curves (a) were calculated from equations (6) and (7) and curves (b) from equations (11) and (12). The points obtained by the step-by-step method agree very well with the analytical curves.

For Fig. 4 the valve characteristics are parabolic. Curve (a) was calculated by integrating equation (9). For all the curves $I_a = kV_g^2$, $k_1R_1 = k_2R_2 = 1\text{V}^{-1}$, $C_2 = 0$, $\rho = 1/2$, $V_{1S0} = 1/3$ and $V_{2S0} = 3$. (The beginning of the curves, at $t = 0$, corresponds to $v_1 = -0{\cdot}25$; V_{2g}, v_2 and V_{1g} are immediately calculable, V_{1g} producing a current in V_1 which is more than enough to sustain $v_1 = -0{\cdot}25$). The curves show that taking t_3 as $0{\cdot}105\ t_1$ distorts the time scale by no more than 10%.

The curve (c) of Fig. 3 is reproduced in Fig. 5 and compared with one showing the effect of making $R_2C_2 = R_1C_1$, conditions otherwise being unchanged and another using the characteristics of the CV138 shown in Fig. 2 in place of the artificial parabolic law, with $C_2 = 0$, $R_1 = R_2 = 1000\Omega$, $\rho = \frac{1}{2}$ and initial conditions of unity loop gain ($g_{10} = 0{\cdot}67$ mA/V and $g_{20} = 6{\cdot}0$ mA/V). In calculating curve (b) the value of V_2 at the time when v_1 has reached $-0{\cdot}25$ (assuming the triggering pulse to have been very small indeed) is not immediately calculable, but equations (6) and (7) assist in estimating it. The transition is slower when CV138 valves are substituted for types with a parabolic law connecting I_a and V_g, because g changes less rapidly with V_g near cut-off for the practical valve.

The practical consideration that the circuits are more likely to be triggered by finite pulses applied to G_1 of V_1 or V_2 detracts little from the value of the comparison between the separate curves of Figs. 4 and 5, for which only very small displacements of an anode voltage are assumed at $t = 0$.

* The apparently odd choices are explainable: $e^{-0{\cdot}69} = 0{\cdot}50$ and $e^{-0{\cdot}105} = 0{\cdot}90$.

The curves of Figs. 4 and 5 have not been shown much extended beyond the point at which V_2 is cut off (i.e., into the t_b region). Thereafter when $C_2 = 0$, v_1 follows an easily calculated exponential curve, convex upwards, and when $R_2C_2 \approx R_1C_1$ both v_1 and v_2 follow exponential or near-exponential curves.

5. Discussion

The analyses call for little comment. They are thought to serve a useful purpose in clarifying the operation of the circuit during the transition and, by giving a guide to the smallness of step required for a prescribed accuracy, to improve the usefulness of the step-by-step method. It would be wrong, however, to assume that they can readily provide accurate data for everyday circuit design. The main reasons for their inability to do so are bound up with the role of the triggering pulse after positive feedback could have taken sole control, engineering questions and the practical quiescent conditions.

The essential role of the triggering pulse—of bringing the circuit to the point where positive feedback can take control—needs no further explanation, but the optimum size and duration do. Some understanding has been sought by extending the simpler parts of the present analysis to take account of the return of S after a short interval. But further extension introduces more and more mathematical complications the more nearly the theoretical circuit approaches the practical; a full analysis would, in addition, need to consider carefully what was meant by 'best' operation of the circuit; e.g., to consider the relative weights to be given to the achievement of a high rate of change of v_1 and to the minimizing of the overall movement of all the electrode potentials in order to ensure the most rapid reversal of operation.

Engineering questions abound in the Eccles-Jordan circuit. The departures of the valve characteristics from one another and from the parabolic law assumed are probably amongst the least important. Tolerances on resistors and power-supply voltages make themselves felt mainly in their influence on the quiescent conditions. They alone force one of the valves to be well cut off for each stable state—an undesirable condition also imposed by the likely shapes of valve characteristic, particularly the parabolic and near-parabolic. For while (a) $\rho_1\rho_2R_1R_2g_{10}g_{20}$ should be nearly unity in each quiescent stable state for the easiest triggering (b) $\rho_1R_1(I_{1max} - I_{1min})$ should not exceed the grid base of V_2, say v_{b2}, and $\rho_2R_2(I_{2max} - I_{2min})$ must not exceed the grid base of V_1, v_{b1}; i.e.,

$$\frac{\rho_1\rho_2R_1R_2(I_{1max} - I_{1min})\,(I_{2max} - I_{2min})}{v_{b1}\ .\ v_{b2}} \gg 1$$

where I_{1min} and I_{2max} represent the currents passed by V_1 and V_2 respectively for one quiescent state and I_{1max} and I_{2min} the other. But $\frac{I_{1max} - I_{1min}}{v_{b1}} = \bar{g}_1$, the mean value of g_1, and

$$\frac{I_{2max} - I_{2min}}{v_{b2}} = \bar{g}_2$$

the mean value of g_2. Now $\bar{g}_1 . \bar{g}_2$ may well exceed $g_{10} . g_{20}$; if it does (a) and (b) cannot simultaneously be satisfied. If v_{b1} and v_{b2} are gradually extended into the cut-off region (making I_{1min} and I_{2min} zero incidentally) $\bar{g}_1$ and $\bar{g}_2$ are reduced so that (b) is more easily satisfied. But (a) ceases to be true and the need for a larger triggering pulse arises. The analysis would have encountered the same problem had it concerned itself with restoration (or backward operation) of the circuit to the initial stable state. Thus the initial conditions chosen for the circuit of Fig. 1 to give the curves of Figs. 4 and 5 cause V_2 to be well cut off after the circuit has changed over to its second stable state; although only a minute triggering pulse of the shortest duration is needed for forward operation, a large one of much longer duration would be needed to initiate backward operation.

Figs. 6 and 7 have, therefore, been included to illustrate the importance of these very practical features of the Eccles-Jordan circuit. Their curves have been calculated by the step-by-step method with $t_s = 0{\cdot}105t_1$; the potentials of the electrodes of V_1 and V_2 for one stable state are exactly those of V_2 and V_1 for the other. For each valve $I_a = k(V_g - V_{g0})^2$ when $V_g > V_{g0}$, and $I_a = 0$ when $V_g < V_{g0}$; $k = 1\,\text{mA/V}^2$, $R_1 = R_2 = 1{,}000$ ohms, $\rho = \frac{1}{2}$ and $C_1 = C_2$.

For Fig. 6, before the operation of S at $t = 0$, $V_{1g} = 3 + V_{g0}$ and $V_{2g} = V_{g0} - 1{\cdot}5$; therefore $I_1 = 9$ mA, $I_2 = 0$ and the loop gain is zero. E, -3 volts, is introduced at $t = 0$, thereby depressing the potential of G_1 of V_1, reducing I_1 to zero and so on. At a later time, $t = t_s$, S returns and the extent to which the circuit has then been disturbed determines whether a changeover (to the second state for which $V_{2g} = 3 + V_{g0}$ and $V_{1g} = V_{g0} - 1{\cdot}5$) will result or whether, on the other hand, the circuit will return to the conditions applying before $t = 0$.

For Fig. 7, before the operation of S, $V_{1g} = V_{g0} - 1{\cdot}5$ and $V_{2g} = V_{g0} + 3$. E, now $+3$ volts, is introduced by the operation of S at $t = 0$, raising the potential of G_1 of V_1, etc. At $t = t_s$, S returns and the disturbed circuit is left to decide its movements.

The two figures show the importance of the length of t_s. On the one hand, if t_s is less than some minimum value, no transition results, even though V_{1a} may have moved nearly as far as it would had a transition resulted (see for instance, the curve for V_{1a} when $t_s = 1{\cdot}47\ t_1$, in Fig. 6). The practical dangers following a 'near-miss' at once become apparent; they are, moreover, not necessarily avoided merely by ensuring that the motion of the anode of the non-triggered valve shall be taken as the output signal (see for instance the curve for V_{2a} when $t_s = 1{\cdot}37\ t_1$, of Fig. 7). On the other hand if, for the conditions of Fig. 7, t_s much exceeds the minimum duration necessary to ensure a transition, the circuit may suffer an unnecessary disturbance and t_b may outweigh t_c in importance. The disturbance would militate against a rapid reversal to the original state by a second triggering pulse applied, for instance, to G_1 of V_2. (A more detailed study shows the same danger to exist in practice even when the triggering pulse acts to turn off a valve, as for Fig. 6.)

Fig. 6 shows incidentally, in the curves for $t_s \geqslant 2{\cdot}1t_1$, how positive feedback loses its importance when the triggering voltage lasts too long. Moreover those parts of the curves for $t < 1{\cdot}6t_1$, belong to the region of t_a rather than of t_c.

For the circuit considered, which closely resembles a typical practical one, the minimum effective value of t_s is about $1{\cdot}6t_1$. Hence if $C_1 = C_2 = 12$pF, R_1 and R_2 each being 1,000 ohms, a triggering pulse of 3 volts is effective if it lasts 20 milli-microseconds. If the voltage of the pulse were greater, one direction of the switching—that started by the triggering pulse applied to turn a valve on—could be effected by an even shorter pulse. The smallness of the minimum value of t_s effecting a transition undoubtedly makes easier unwanted transitions of high-speed Eccles-Jordan, and closely related, circuits. They are known to occur, for instance, when electrical discharges of short duration, possibly producing short bursts of radio-frequency energy, have been produced near either a circuit or its power leads.

The time constant t_1 (and t_2 where it differs from t_1) figures prominently in the expressions relating the electrode potentials with time. Designers of Eccles-Jordan circuits should always pay attention to it. If, for instance, a circuit is to be used to select pulses of more than some specified duration, t_1 must be carefully chosen. But t_1 is not entirely at the designer's disposal; the valve characteristics alone set a lower limit. C_1 (and C_2) cannot be reduced below the sum, $C_a + \rho_1 C_g$ (or $C_a + \rho_2 C_g$), of the anode capacitance of one valve and a contribution from the grid capacitance of the other. R_1 and R_2 must be sufficient to satisfy $g_1 g_2 R_1 R_2 \rho_1 \rho_2 > 1$. Thus if $C_1 = C_2$, $R_1 = R_2$ and $\rho_1 = \rho_2 = \rho$

$$C_1R_1 < (C_a + \rho C_g)/\rho\sqrt{g_1g_2},$$

which has its smallest value, $(C_a + C_g)/\sqrt{g_1g_2}$ when ρ has its maximum value of unity (in practice the power supplies available limit ρ to some smaller value, thereby increasing t_1).

Only a simple Eccles-Jordan circuit has been considered. Although it is still freely used, the demands for circuits with two stable states have been numerous and varied and have led to many modifications to it. Thus, diodes are often used to limit the excursion of one or more electrodes; 'speed-up' capacitors are connected across R_1 and R_2 to transfer, initially, more of the change of voltage at the anode of one valve to the grid of the other; and the suppressor grids of the pentodes can often more conveniently accept the triggering pulse. A rigid analysis of any more complicated circuit must be expected to be lengthy and probably unwieldy; it can hardly lead quickly to results which will compete in usefulness with the step-by-step method.

Acknowledgment

Acknowledgment is made to the Engineer-in-Chief of the General Post Office for permission to make use of the information contained in this paper.

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TRAVELLING-WAVE TUBES WITH DISPERSIVE HELICES

By F. N. H. Robinson, M.A.

(Royal Naval Scientific Service)

THE travelling-wave tube (t.w.t.) as a microwave amplifier has been described by R. Kompfner[1] and J. R. Pierce and L. M. Field[2]. Essentially (Fig. 1) the t.w.t. consists of a helix of wire in which the signal propagates at a velocity in the region of $\frac{1}{20}$ to $\frac{1}{10}$ the velocity of light, and down the centre of which a beam of electrons with the same velocity as the signal is projected. The electrons interact with the wave by velocity modulation and bunching, and amplification results. Theories of this process have been given by Pierce[3], Kompfner[4] and Bernier[5] which all agree and predict the dependence of the gain on such parameters as beam current and voltage with a fair degree of success.

Now a travelling-wave tube is essentially an amplifier which has an internal feedback path, the helix, and unless this is correctly matched to the external circuit at both ends, power is reflected back from the output of the tube to the input and it oscillates. In the early work (e.g., Kompfner[4]) it was found very difficult to obtain gain of more than 10 db without the tube oscillating, though not necessarily at the signal frequency. This was because the electronic bandwidth (i.e., the band over which wave-electron interaction and amplification occur) was very wide, of the order of an octave or more; and although it was possible to get a good helix-to-circuit match over a bandwidth of, say, 50% in the neighbourhood of the signal frequency, it was not possible to obtain a sufficiently good match over the whole electronic

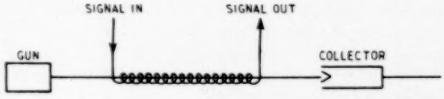

Fig. 1. *Schematic travelling-wave tube.*

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bandwidth to prevent oscillation occurring at some frequency far from the signal. Pierce and Field[2] overcame this difficulty by making the helix have an attenuation in excess of the net gain of the tube. This is possible because the effect of attenuation in the helix on the amplification can be compensated by an increase in beam current, whereas the unwanted wave reflected back from the mismatch at the output end does not interact with the beam, because it travels in the opposite direction, and suffers the full attenuation of the helix. Thus if the helix loss is L db and the reflection coefficient due to mismatch at either end is K the tube will be stable up to a maximum gain

$$G = L - 20 \log K \text{ db} \quad .. \quad .. \quad .. \quad (1)$$

If we assume that at some frequency within the electronic bandwidth K will be unity, then the maximum stable gain is equal to the cold loss of the helix. Tubes using this principle having gains greater than 20 db have been reported[2].

It is, however, possible to reduce the electronic bandwidth considerably by using a dispersive helix; i.e., a helix in which the phase velocity of the wave it supports varies rapidly with frequency. There will then be only a limited range of frequencies within which the electron and wave velocities are sufficiently close for amplification to occur. This is achieved in practice by making the helix diameter sufficiently small. If the helix radius is r and the axial wavelength λ (i.e., the wavelength of the slow wave in the helix) then dispersion occurs when:

$$d = \frac{2\pi r}{\lambda} < 2 \quad .. \quad .. \quad .. \quad .. \quad (2)$$

With this parameter d made equal to 1.2 there is sufficient dispersion to reduce the electronic bandwidth to about 10% of the centre frequency.

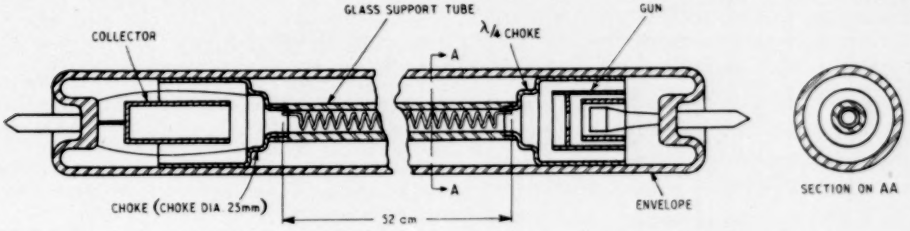

Fig. 2 (above). *Dispersive travelling-wave tube.*

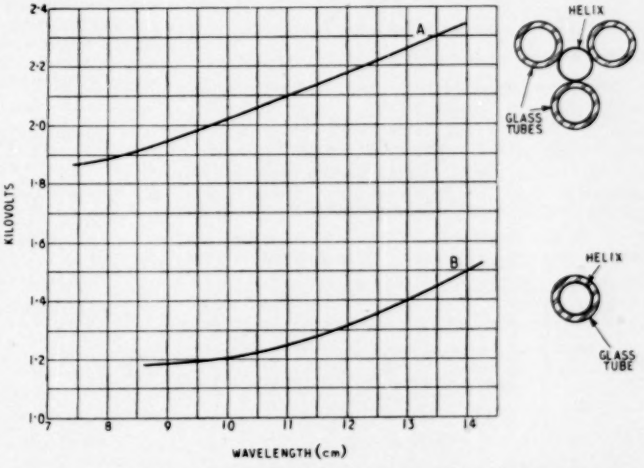

Fig. 3 (right). *Beam voltage for maximum gain for two similar helices supported in different ways.*

It is then feasible to terminate the helix correctly over the whole of this band, and by virtue of equation (1), since K is now fractional, to obtain stable gains greatly in excess of the cold loss L.

The magnitude of the increase in stable gain we can hope to achieve by this method can be estimated as follows:—

If the attenuation in the helix is L db and the measured insertion loss of the tube is L' db then the difference $L' - L$ is due to mismatches at the ends. It seems plausible that if over a band of 500 Mc/s L' only varies by 2 db, the minimum value of L' cannot be very different from L. Thus using the relation

$$L' - L = -20 \log (1 - K) \quad .. \quad .. \quad (3)$$

we can obtain K and use the value in equation (1)

to predict G. For instance, if within a band of the same order as the electronic bandwidth $L'-L \leq 2$ db, then within that band G may exceed L by 14 db.

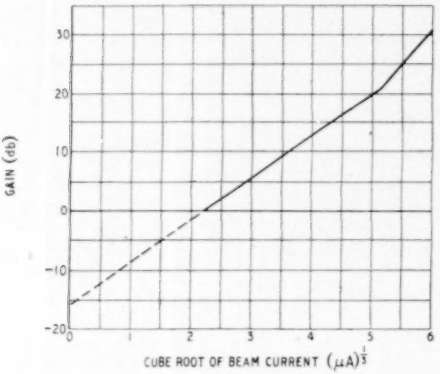

Fig. 4. *Gain as a function of $i^{1/3}$ at $\lambda = 11{\cdot}85$ cm.*

Tubes have been made to test this hypothesis and results will be quoted for a tube having a helix of 3 mm internal diameter, 12 turns per cm, 52 cm long of 0·4-mm molybdenum wire; this tube is shown in Fig. 2. The helix is supported in a hard-glass tube of approximately 1-mm wall thickness, and this appears to have no harmful effect on the dispersion of the helix although it reduces the phase velocity quite considerably.

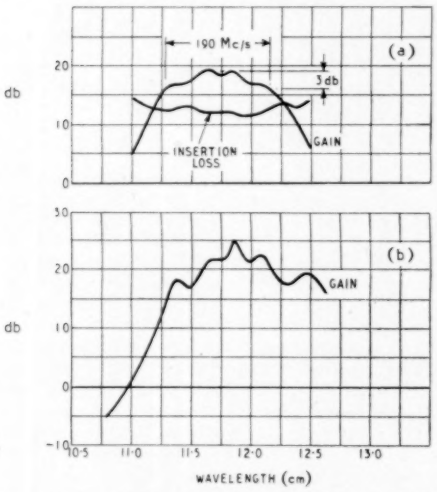

Fig. 5. *Gain and loss as functions of wavelength; h.t. 1310 V. (a) Current 110 μA; (b) current 155 μA.*

The attenuation due to loss in the glass is incidental and no deliberate attempt has been made to introduce loss. Fig. 3 gives a comparison of the beam voltage corresponding to the wave velocity for two identical helices, one supported in a glass tube, the other between three glass tubes. Fig. 4 shows the relation between gain and the cube root of the beam current and shows the usual straight line with a deviation over 21 db presumably due to a feedback effect. The tube is quite stable and the gain repeatable up to 33 db, but it is clear from a comparison of (a) and (b) of Fig. 5, which show gain versus wavelength, that at 24 db gain there is a resonance effect which is absent at lower gains. There is at 24 db, however, no oscillation occurring at any wavelength between 7 and 14 cm. It seems unlikely that there will be any oscillation beyond these limits. The cold insertion loss of the tube is 11·5 db.

Fig. 6 is a curve of gain versus beam voltage for a given current and frequency. It is precisely similar to that obtained with a non-dispersive tube as many wavelengths long. From this and Fig. 7,

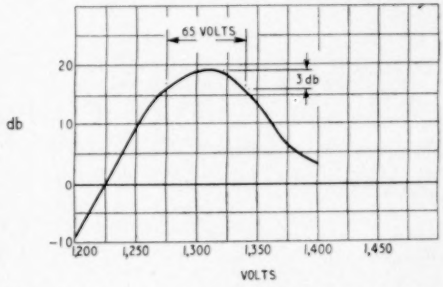

Fig. 6. *Gain as a function of beam voltage; $\lambda = 11{\cdot}85$ cm; beam current 110 μA.*

which is an enlarged version of part of curve B of Fig. 3, we can predict that the bandwidth of the tube between half-power points will be 180 Mc/s and that the bandwidth for a 12-db decrease in gain will be 500 Mc/s. These values are in close agreement with those shown in the measured frequency response, Fig. 5(a). On the basis of these curves the fact that the tube operates stably at 19 db gain with only 11·5 db insertion loss is readily explicable.

Fig. 8 gives a rough indication of the expected maximum stable electronic gain G_e calculated on the basis of

$$G_e = L + G = 2L - 20 \log K \text{ db} \quad \ldots \quad (4)$$

and equation (3). It can be seen that if $L \geqslant 11$ db the tube is everywhere within the stable region.

The dispersive tube is, as can be seen from Fig. 6, no more critical of beam voltage than other travelling-wave tubes. Its bandwidth is, however,

considerably less, although there is no reason why, if the matching arrangements at the end of the tube could be made sufficiently broad, the dispersiveness of the helix should not be reduced and the electronic bandwidth thereby increased to take advantage of the broader matched band.

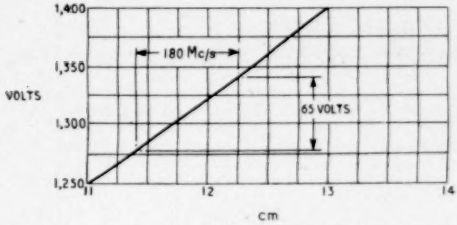

Fig. 7. *Voltage for greatest gain as a function of wavelength.*

The main and most obvious advantage of the dispersive t.w.t. is that the beam current required to obtain a given gain is reduced. Fig. 4 shows that with 125 μA the gain is 20 db while tubes in which stability is achieved by the introduction of loss into the helix are reported to need currents of several milliamps to achieve the same gain. As a result a dispersive t.w.t. is very much less noisy. The tube quoted has a noise factor of better than 17 db at 2500 Mc/s when operated with 20 db gain. Noise factor F is defined as

$$F = 20 \log_{10} \frac{\text{S/N ratio at input}}{\text{S/N ratio at output}}$$

There are several reasons why one would expect such a tube to have a comparatively low noise factor:—

(1) Reduced beam current for a given gain, which itself is due to (a) low insertion loss and (b) higher helix impedance.

(2) Less current is lost to the helix because with such low beam currents it is possible to design a more efficient gun, and there is therefore less partition noise.

(3) There is less partition noise due to non-uniform coupling to the field of the helix, because in general the axial field in dispersive helices is more uniform than in non-dispersive ones.

The above arguments are based on the assumption that space-charge smoothing exists in travelling-wave tubes. This is borne out by measurements which indicate a space-charge smoothing factor of the order of 10^{-1} to 10^{-2} (see also Kompfner[4]). In these tubes the actual current lost to the helix has been of the order of a few per cent with beam currents of the order of 100 to 200 μA.

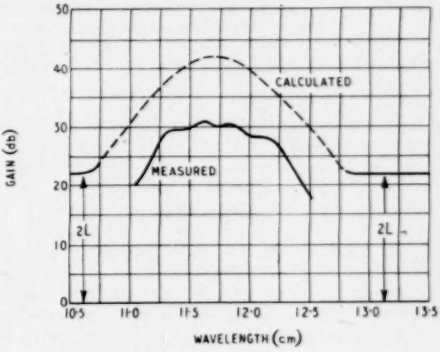

Fig. 8. *Calculated and measured stable electronic gains.*

Acknowledgment

This work was carried out for the Royal Naval Scientific Service and the author wishes to express his gratitude for permission to publish it. The substance of this paper was previously presented at the "I.R.E. Electron Tube Conference" at Cornell University in 1948.

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VOLTAGE-CONTROLLED SECONDARY-EMISSION MULTIPLIERS

Their Construction and Application

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SUMMARY.—Difficulties with life in secondary-emission amplifier valves have been overcome by employing a layer of caesium oxide kept at a temperature below 180°C. Several constructions of experimental valves are shown and their characteristic properties described. A variable-mu valve and a very-high-slope valve employing four stages of multiplication are shown. The use of grid-shaped dynodes (secondary-emission electrodes) is discussed. Some circuits in which secondary-emission valves offer specific advantages are described, especially generators of sinusoidal and non-sinusoidal oscillations and monostable and bistable triggers.

1. Introduction

IN amplifier valves, secondary-emission can be applied to increase the mutual conductance. The anode current is maintained at the usual value. Thus the cathode current is much smaller than usual, resulting in a low input conductance at u.h.f. and a high ratio of mutual conductance to current. This ratio is kept constant during the secondary-emission multiplication. Thus the mutual conductance at the anode is much larger than can be obtained without secondary emission. On the other hand, in a secondary-emission valve (s.e. valve) some additional noise is introduced by the secondary-emission process. The s.e. valve is, therefore, especially suitable for wideband amplification in those stages where the noise is not a limiting factor.

Hitherto s.e. amplifier valves have not been extensively used. One of the reasons is the price. It will be shown later that the use of s.e. valves in wideband amplifiers in many cases involves a smaller number of valves than at first seems necessary, because the practical increase in voltage gain per stage is higher than the increase of the wideband figure of merit.

There is also another reason. Not long ago s.e. valves, in some cases, had a considerably shorter life than normal valves, due to a loss of the s.e. multiplication. Unpublished investigations of C. F. Veenemans have revealed the causes of this occasionally occurring short life. S.e. valves can now be constructed with a life which will be quite satisfactory provided the valves are not overloaded.

The application of s.e. valves can give specific advantages, not only in amplifiers, but also in generators and in other circuits in which the non-linear properties of valves are used. In the last decade considerable progress has been made in the development of such circuits.

MS accepted by the Editor, June 1950

For these reasons it seemed important to publish part of the work done in this field since our former paper on this subject.[1] First, the construction of the output system of a s.e. amplifier valve is discussed, especially with reference to the case where only one stage of multiplication is employed. The second part concerns the construction of a s.e. amplifier valve with a gain control free from input capacitance and conductance variations. The third part deals with some constructions of a voltage-controlled electrostatic multiplier with more than one stage of multiplication. In the fourth part the construction of a multistage multiplier is described in which the dynodes have the shape of grids. In the last part some circuits are briefly discussed in which s.e. valves have specific advantages. Several important considerations relative to the construction and use of a s.e. valve, especially its u.h.f. properties and its noise, will not be discussed.

2. The Output System of a Secondary-emission Amplifier Valve

The Anode-current–Anode-voltage Characteristic

The construction of the last dynode and the anode largely determines the anode-current–anode-voltage characteristics of a s.e. valve. Fig. 1 shows such characteristics schematically. E_a is the anode voltage, I_a the anode current, E_d the voltage of the last dynode. Not until $E_a > E_d + \Delta E_a$ is the anode current saturated. To determine the value of ΔE_a the output system can be regarded as a diode in which the electrons emanating from the secondary cathode have initial velocities much greater than in the case of a thermionic cathode. This means that the anode current is less limited by the space charge, while on the other hand a grid-like construction of the anode can give rise to electrons which, after passing the anode twice, fall back on the dynode.

In Fig. 1 the full line represents an idealized characteristic, taking into account large variations in anode and dynode voltage. The dotted lines show deviations occurring in practical valves originating from different causes. Practically the whole electron beam should strike the last dynode.

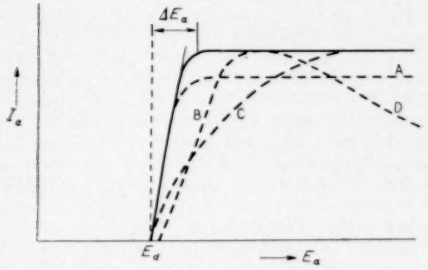


Fig. 1. *Anode-current–anode-voltage characteristics of s.e. valves. The fully-drawn curve shows an ideal characteristic, the dotted curves representing deviations due to various causes.*

If this is not the case then characteristic A will appear. With a grid-shaped anode [Fig. 2(a)] the wires of the grid will absorb only a small part of the primary current. If, however, the beam is so wide that its edges touch the side rods of the grid, decrease in secondary current may be appreciable. With a small distance between anode and dynode the saturation of the dynode current will occur at a small value of ΔE_a; a large distance [Fig. 2(b) and characteristic B] not only results in a large value of ΔE_a but also reduces the anode capacitance. On the other hand the variation of the anode capacitance with anode current will be greater in case B. In Fig. 2(c) the distance between anode and dynode varies for different parts of the beam. This will result in characteristics like C in Fig. 1.

Negative Anode Conductance

Fig. 2(d), (e) and (f) give three typical examples of constructions in which the characteristic D of Fig. 1 will appear. Generally a negative internal resistance of the anode will occur when an increase in anode voltage results in an increase of the primary current to the anode. The total anode current will then decrease because an increasing part of the primary current is not multiplied. This phenomenon can be turned to advantage when a positive conductance of the anode is neutralized by an equal negative conductance, the result being an infinite value of the internal resistance. With the system of Fig. 2(e) a negative internal resistance will not appear with one stage of secondary emission when $E_d/E_a > \cos^2 \alpha$. Otherwise the primary electrons between the grid-shaped part of the anode and the dynode will describe parabolic paths and will not reach the surface of the dynode. Thus with $\alpha = 45°$ E_a should be smaller than $2E_d$ and with $\alpha = 30°$ smaller than $4/3E_d$. It is obvious that in practice the angle between the direction of the beam and the plane of the grid should be nearer 45° than 30°. A similar deviation will occur with the construction of Fig. 2(c) if the primary beam is so directed that with increasing anode voltage an increasing part of it strikes the anode [Fig. 2(f)]; ΔE_a will be smaller here than in the case of Fig. 2(c). In the construction of Fig. 2(d) there are two possibilities for a negative anode conductance: the primary electrons which are at the extreme right may strike the anode at once, while the primaries which are a little more to the left may strike it after having described a parabolic path when the anode voltage is made too high. Of course, in practice, the characteristics will often show more than one of these defects at the same time.

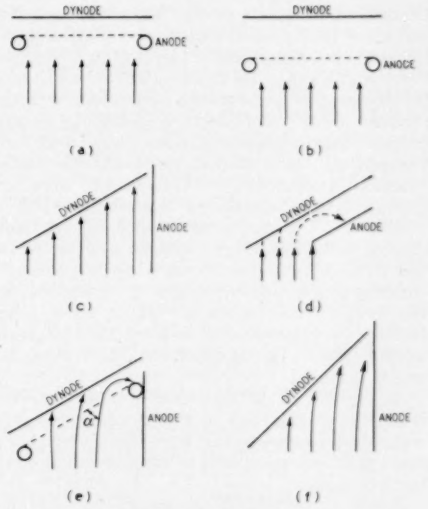


Fig. 2. *Typical output systems of s.e. valves.*

Dynode Out of Sight of the Cathode

In former experiments the output system was mounted in such a way as to prevent materials evaporated from the cathode from reaching the dynode. Fig. 3 shows the cross-sections of two experimental valves constructed in this way. The first is very simple but has the disadvantage that before reaching the anode grid wires the secondary electrons have to travel a long way. This results in a large anode conductance at high frequencies. Also the primary beam has a tendency to form

gradually a virtual cathode between screen grid and anode. At relatively low beam currents g_m/I will be lower at the anode than at the cathode. In Fig. 3(b) the anode is composed of a grid-shaped part and a plate. This results in a low output conductance. But the output capacitance is rather high.

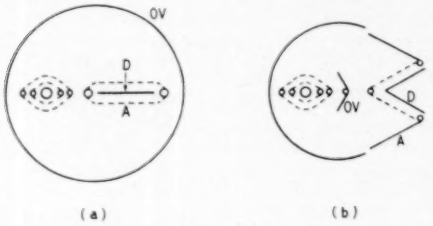


Fig. 3. *Cross-sections of two constructions of s.e. valves in which the dynode is placed out of sight of the cathode.*

In these structures at first a layer of oxides of alkaline earth metals, mainly MgO, was used at the surface of the dynode. But this layer often showed the cold emission described by Malter.[2] Moreover there were difficulties in manufacture and the life performance was not stable. Therefore, a layer of caesium oxide, obtained by reducing oxidized copper with caesium vapour, was next used. Veenemans then showed that the secondary-emission properties of this layer were only preserved so long as its temperature did not exceed 180°C. Moreover he discovered that a dynode with this layer could be used in sight of the cathode without losing a large part of its emissive property in operation. It is supposed that the evaporating Ba-metal, which itself is only slightly secondary-emissive, is oxidized by caesium oxide to BaO. The caesium metal then evaporates and is gettered.

As cooling of the secondary-emission electrode is necessary, the back of this electrode is covered with black particles of nickel[3]; this material at the same time being capable of binding small quantities of caesium.

Another method of increasing the life is to reduce the cathode temperature.[4] Life tests revealed that with a caesium-oxide dynode the cathode temperature is not critical so long as the dynode temperature is kept below 180°C.

Dynode in Sight of Cathode

Fig. 4 shows a number of cross-sections of electrode mountings in s.e. valves in which the dynode is not shielded from cathode evaporation. Fig. 4(a) has the disadvantages of a grid-shaped anode already mentioned. Moreover the anode capacitance is very high. In Fig. 4(b) the drawbacks of the grid-shaped anode have been removed but the anode capacitance is high. A construction like that of Fig. 4(c) has a small anode capacitance but ΔE_a is large due to incomplete saturation of the dynode current. Fig. 4(d) is a cross-section of the mounting of a valve EFP60. Each of the two beams emanating from the cathode is split into two parts, one to the right and one to the left of the small ribbon-shaped anode. They impinge on the inner wall of a gutter-like dynode. In spite of the small anode capacitance the value of ΔE_a (Fig. 1) is very low. The dynode has large cooling fins so as to keep its temperature below 180°C. In the construction of Fig. 4(e) the primary beams are also split into two beams, but at each side of the cathode there are two bar-shaped anodes each drawing one quarter of the secondary current. The properties of an experimental valve having this construction especially developed for use at u.h.f. can be found in an article by G. Diemer and J. L. H. Jonker.[5] Fig. 4(f) shows another output system combining low anode capacitance with a low value of ΔE_a. The anode and the dynode are shaped in such a way that, at the highest possible anode voltage, the primary electron beam runs

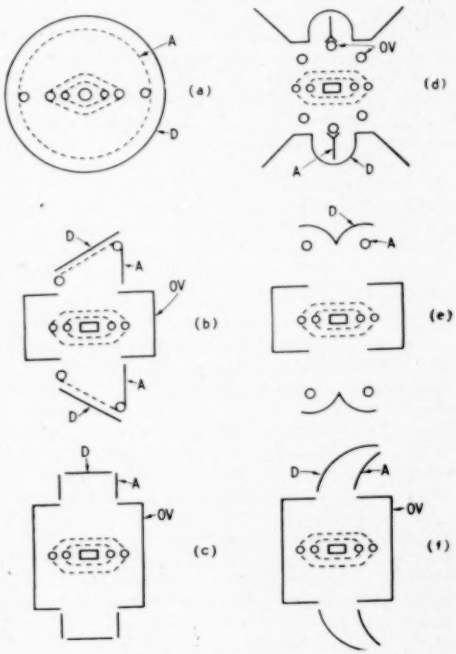


Fig. 4. *Cross-sections of s.e. valves in which the dynode is placed in sight of the cathode.*

just along the surface of the anode without touching it. At the lowest possible anode voltage the primary beam strikes the surface of the dynode at a place where the distance to the anode is so small that the secondary current will flow entirely to the anode.

3. A Secondary-emission Variable-mu Valve

For a long time the need has been felt for an amplifying valve with a very high mutual conductance which can be varied without involving any appreciable change of the input capacitance. It was for this purpose that the orbital-beam multiplier was developed.[6] This valve, however, required a control voltage of about 80 V. Fig. 5 shows in cross-section a s.e. control valve, the input capacitance of which changes but little and for which a control voltage of only about 20 V is needed.

A cathode 1 of rectangular cross-section is surrounded by a control grid 2 and a screen grid 3 and emits two beams with little spread. There is a fairly great distance between the screen grid and the next control grid. This control grid is slightly tilted, so that when the electrons are returned the whole of the beam impinges upon the plate 4 connected to the screen grid. Thus, when the mutual conductance is changed with the aid of the voltage E_{g_3}, the returning electrons do not affect the input admittance. The screen grid is directly connected to the supply voltage, so that there will be only a slight variation in its potential as a result of the variations in current arising from the change of mutual conductance, and the resulting variation in input capacitance remains small. The high screen-grid potential E_s of 250-300 V makes it difficult to get a very low control voltage.

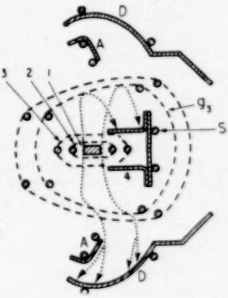


Fig. 5. *Cross-section of a variable-mu s.e. valve. The grid-cathode capacitance is kept constant.*

How a Low Control Voltage is Obtained

Since the paths of the electrons are little affected by the plane of the screen grid but greatly influenced by the plane of the control grid, we shall consider the case of a space bounded by a screen grid and a control grid parallel to each other, with the electrons entering that space under an angle α with the normal to the screen grid [Fig. 6(a)]. If the control grid voltage is adjusted so that the electrons are not allowed to pass through, the paths they describe are parabolic and $E_{eg} = E_s \frac{r^2}{16d^2}$, where E_{eg} is the effective potential in the grid plane.

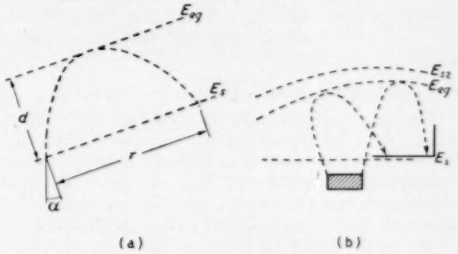


Fig. 6. *Parabolic paths of the electrons between screen grid and second control grid of the variable-mu valve.*

Thus a positive potential lower than E_{eg} in the plane of the control grid will hold back the electrons; with $E_s = 250$ V and $r/d = 0{\cdot}8$ this potential is 10 V. The voltage E_g applied to the control grid may not, however, exceed 0 V and the largest possible proportion of the electrons has to be passed through at that voltage. To attain this it is necessary in the first place that E_{eg} be kept low. Since r is governed by the width of the cathode and the spread of the beam, the value of d must be chosen to allow for the extra spread due to the space charge. In order to keep the control voltage as low as possible the local variations of the potential in the plane of the control grid have to be small, so that with $E_g = 0$ V only a relatively small part of the grid plane will have a potential higher than $E_s\, r^2/16d^2$. Nevertheless the major part of the electron current has to pass through when $E_g = 0$, and, therefore, the distance to the next, fourth, grid was kept small.[7]

Furthermore, it was found advantageous to give

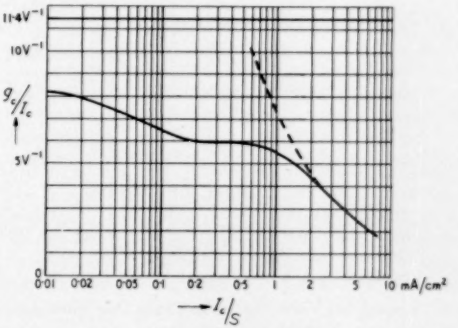


Fig. 7. *The dotted line shows how g_c/I_c would be dependent on I_c/S if the law $I_c = cE^{3/2}$ were valid up to very small values of I_c. In practice the fully-drawn line is measured.*

the control grid and the next screen grid such a curvature that the consequences of the spread due to the space charge are somewhat reduced and the electrons passing the screen grid farthest from the intercepting plate 4 describe a parabolic path with a smaller curvature than that followed by the electrons passing close to the intercepting plate [see Fig. 6(b)].

The Electrode System

The basic system is shown in Fig. 6(b), from which a valve was built up as depicted in the horizontal cross-section in Fig. 5. When passing through the control grid the electrons have a rather high tangential velocity. Consequently, the anode had to be placed at a rather great distance in the same direction in order that the electrons should strike the auxiliary cathode at a point where the distance between dynode and anode is shortest.

The variation in capacitance of the control grid obtained in this way when regulating the anode current amounted to about 0·01 pF with a control voltage of 20 V. The variation of the anode capacitance was greater and dependent upon the anode voltage. This is understandable considering the paths followed by the primary and secondary electrons between dynode and anode.

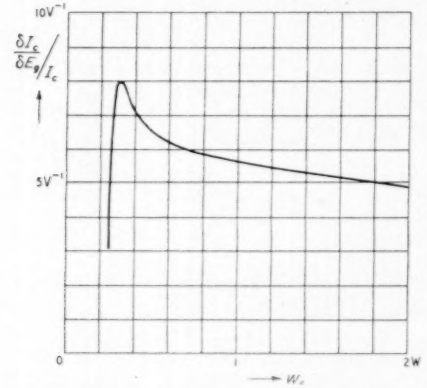


Fig. 8. *Dependence of g_c/I_c on the heater wattage.*

The paths of the primary electrons have been drawn in dotted lines in the lower half of Fig. 5 for two anode voltages, viz. 4/3 and 2 × the dynode voltage. In the latter case the edge of the primary electron beam follows the curvature of the anode.

4. Amplifying Valves with More than One Secondary-emission Multiplying Stage

With the usual dimensions of cathode and control grid the density of the cathode current in the case of single-stage multiplication in the working-point is mostly so great as to give rise to a plane of minimum potential, the Epstein minimum, close to the cathode. In that case the ratio g_c/I_c (in which $g_c = \delta I_c/\delta E_g$) is approximately inversely proportional to the 2/3 power of the strength of the current. To get the highest possible value of this ratio a number of secondary-emission stages are applied, so that with the same anode current the value of I_c becomes small.

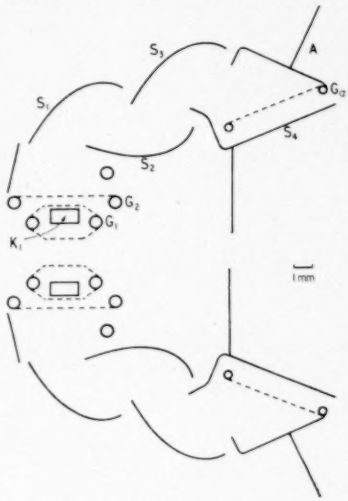


Fig. 9. *Cross-section of a push-pull four-stage s.e. valve. Each side has a slope of 50 mA/V at $I_a = 10$ mA.*

Experiments have shown that when the current density at the cathode is reduced a kind of saturation takes place long before the theoretical limit e/kT is reached and that it is only with very small densities of current that the ratio g_c/I_c becomes more than 2/3 of that theoretical limit. In Fig. 7 this ratio has been plotted as a function of the current density for a construction where the distance between the cathode and the control grid is 0·11 mm; the grid wires were 0·03 mm thick and spaced 0·09 mm apart. The control-grid voltage was so adjusted that the grid current amounted to 1% of the cathode current. With a current density greater than 3 mA/cm² the 2/3-power law applies, but when the current density I_c/S (where S is the surface of the cathode) is less than 1 mA/cm² the ratio g_c/I_c rises but little above half the theoretical limit. The dotted line shows what this ratio would be like if the 2/3-power law also applied for smaller current densities.

These measurements were taken with a cathode temperature of 1000°K, and at lower temperatures the ratio becomes somewhat higher. Fig. 8 shows

the dependency of g_c/I_c upon the filament-current energy.

Fig. 9 gives a cross-section of a push-pull amplifying valve with four secondary-emission stages. When the potential difference between the dynodes was 100 V the total multiplication amounted to 150-200. Part of the supply voltage is needed for feedback in order to stabilize the anode direct current, so that a total voltage of 500 V was used. The mutual conductance of each system was more than 50 mA/V with $I_a = 10$ mA, while the value of $g_m/4\pi\sqrt{C_i C_o}$ was about 800 Mc/s.

5. The Use of Nets as Dynodes

Several investigators have used as dynodes a system of grids or gauzes placed one behind the other. The advantage of this is that it greatly simplifies the construction of a valve with a large number of secondary-emission stages. The greatest drawback, on the other hand, is the fact that with a given total voltage between cathode and anode the secondary-emission factor attainable is smaller than if plates are used as electrodes.[8]

Fig. 10 represents diagrammatically a valve in which the cathode current I_1 rises to a value I_a upon passing through a number of secondary-emission meshes. Assuming that the mesh-works are all of the same construction, that the electrons passing through one all reach or pass through the next one and are arbitrarily distributed over the meshes, and that the potential differences between the nets and between the cathode and the first net are all equal, then the ratio I_2/I_1 will be smaller than I_3/I_2 owing to the fact that electrons will also be reaching the second mesh which have passed twice through the potential difference. For the same reason I_3/I_2 becomes less than I_4/I_3, and so on until a limit is reached for I_{n+1}/I_n. This limit L can be calculated when the potential difference E_o between the nets, their shadow ratio and the trend of the secondary-emission factor δ as a function of the voltage are known.

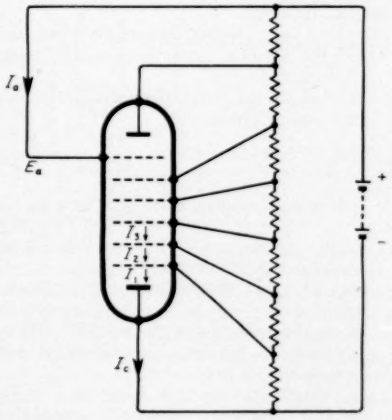


Fig. 10. *The use of gauzes or grids as dynodes.*

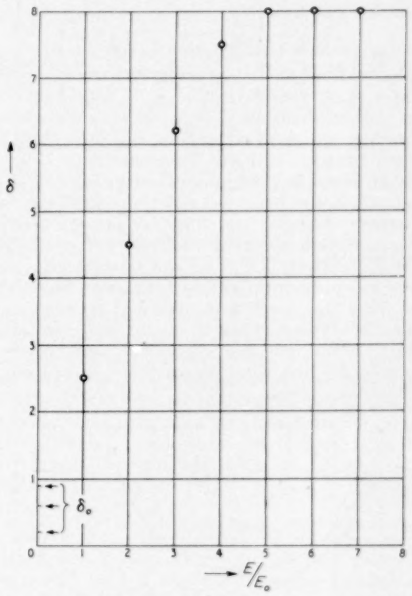


Fig. 11. *Assumed values of the secondary-emission factor used in the calculation of the multiplication in a multiplier with nets as dynodes.*

Calculating the Multiplication per Stage

In this calculation it is assumed that the retention power K of the mesh-works is the same for all velocities of the electrons, that the secondary electrons all emerge at a very low velocity, that the velocity distribution of the electrons between the $(n-1)$th and the nth net is the same as that between the nth and the $(n+1)$th, and that the passage of the electrons is not influenced by space charge. Denoting the secondary-emission factor for electrons having passed m times through the potential difference between two nets by δ_m, then under these conditions the limit value L is found from the equation

$$\frac{1}{K} - \delta_0 = \sum_{m=1}^{\infty} \left(\frac{1-K}{L}\right)^m \delta_m .$$

In practice it appears that L is reached after only three or four stages. For the last multiplying stage usually a plate electrode is employed (see Fig. 10) with a secondary/primary ratio greater than L. This additional multiplication is roughly as great as the loss arising from the first two or three stages having a smaller multiplication than L, so that it may be assumed approximately that the total multiplication is equal to L^n for n multiplying stages.

The Influence of the Reflection Coefficient δ_0

The values of L obtained in practice were greater than those estimated by a rough calculation. Calculations for L were, therefore, made for a number of assumed curves $\delta_m = f(E)$ and for different shadow ratios of the mesh-works. Fig. 11 gives an example of an assumed curve $\delta_m = f(E/E_o)$, where E_o is the potential difference between two successive dynodes. A difficulty encountered in the calculation was that the reflection coefficient δ_0 of the surface of the net for low-velocity electrons was only approximately known. Moreover, this reflection coefficient appeared to have considerable influence upon the value of L. Different values for the reflection coefficient were therefore assumed for the same dependency $\delta_m = f(E/E_o)$ for high velocities.

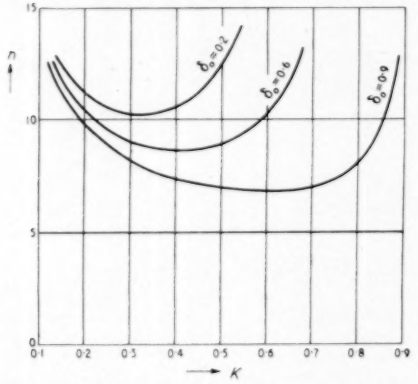


Fig. 12. *The number of multiplier stages needed to obtain a multiplication of* 100 ×. *The horizontal line applies to plate-shaped dynodes, the curved lines to grid-shaped dynodes with various reflection factors* δ_0. *The horizontal variable is the retention power* K *of the mesh-work.*

Fig. 12 shows what number of amplifying stages is required, according to this calculation, to reach a multiplication of 100. The horizontal line for $n = 5{\cdot}0$ relates to dynodes in the form of plates, for which $\delta_1 = 2{\cdot}5$. The other three lines indicate the number of stages required as a function of the shadow ratio K of the mesh-works, from which it appears that with a high reflection coefficient δ_0 of the surface of the nets for low-velocity electrons the number of nets required is not much greater than the number of plate dynodes. When the surface of the nets is of caesium oxide it appears that in practice about 1·5 times as many nets as plates are needed, from which it is to be concluded that the reflectivity is greater than 0·5 and probably about 0·7. According to unpublished measurements taken by J. L. H. Jonker the reflectivity, with an electron velocity of 3 V, may be about 0·8.

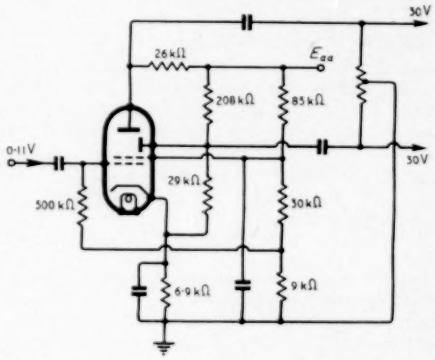


Fig. 13. *Push-pull amplifier. The anode and the dynode are output electrodes.*

6. Some Circuits with Voltage-controlled Multipliers

A secondary-emission grid-controlled valve has several properties which are not found in a normal amplifier valve. They may be summarized as follows :—

(*a*) It has two output electrodes, the anode and the dynode, both with a high mutual conductance.

(*b*) The output currents of these electrodes are 180° out of phase.

(*c*) The mutual conductance $\frac{\delta I_d}{\delta E_{g1}}$ is negative.

(*d*) The mutual conductance $\frac{\delta I_a}{\delta E_{g1}}$ is a multiple of the reciprocal value of the internal resistance of the cathode.

(*e*) The l.f. conductance of the dynode is negative.

(*f*) When the voltages of the output electrodes approach each other their internal resistances fall to a low value.

Various applications result from each of these properties. A number of them will be mentioned here.

Separating Signal Components

Property (*a*) can be used to separate the components of a signal with a simplified circuit or more rigorously than normally. Examples are: video and audio channels, horizontal and vertical synchronizing pulses, high and low pitch audio signals, i.f. and a.f. in reflex circuits.

At the output a two-fold interaction of the two circuits remains: the anode-dynode capacitance and the dependence of the anode current on the dynode voltage, the secondary-emission coefficient normally rising with increasing dynode voltage. If the variable-mu valve mentioned in Section 2 is employed it is possible to amplify two signals in one valve with separate input and output electrodes for each signal.

Push-pull Output

Property (*b*) can be employed to obtain input voltages for a push-pull amplifier or to amplify voltages in such a way that for one or more specified frequencies the output is zero.

In Fig. 13 a valve type EEP1 gives at $E_{aa} = 400$ V an output voltage of 2×30 V r.m.s. with 5% distortion at the input voltage of 0·11 V.

Fig. 14 is an example of a circuit in which at a frequency of 9 kc/s there will not be any output at all as for this frequency the circuit *LC* has so large an impedance that the greater part of the anode alternating current flows through *R* and just equals the negative dynode alternating current.

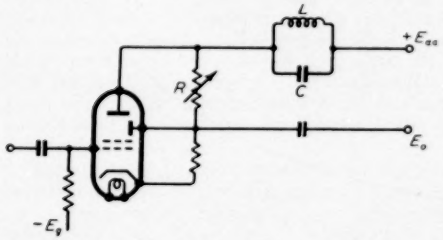


Fig. 14. *The output E_o is zero for the resonant frequency of the circuit LC.*

Amplification of Pulses

When pulses are amplified it is often important that the polarity does not change. One reason is that with short positive pulses it is possible to get a high output with a relatively low direct anode current. The polarity is also important when pulses are mixed, modulated, detected, etc. If the dynode is used as an output electrode the polarity will not change and, with suitable voltages, the pulses can at the same time be selected within two voltage boundaries.

Generation of Waveforms

The properties mentioned under (*c*) and (*d*) are more important than the well-known dynatron behaviour mentioned under (*e*). Fig. 15 gives two possible connections of electrodes in a high-mutual-conductance valve which will result in a

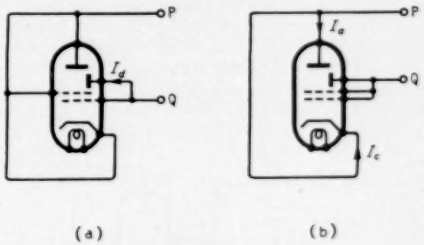


Fig. 15. *Two possible connections of electrodes to obtain between P and Q a dynamic resistance of about minus 100 Ω. The voltage sources are not shown.*

dynamic negative resistance between the points P and Q of the order of minus 100 Ω. The direct voltage sources and separating capacitances are not shown but the voltages should be adjusted so as to obtain a high mutual conductance. There is only a subtle difference between using properties (*c*) and (*d*). In the first case [Fig. 15 (a)] the screen grid is connected to the anode and to the cathode, resulting in a negative resistance $1 \Big/ \frac{\delta I_d}{\delta E_{g1}}$. The absolute value of this resistance is slightly lower than in the second case (b) where the screen grid is connected to the dynode and the signal grid, the reciprocal value of the negative resistance being

$$-\frac{\delta I_c}{\delta E_{g1}} - \frac{\delta I_p}{\delta E_{g1}}.$$

But in this last instance the stray capacitance is lower, as the capacitance between screen grid and signal grid is higher than that between screen grid and cathode. For purposes of comparison the negative internal resistance of a dynatron circuit is of the order of 5 000 Ω,[9] that of a transitron of the order of 1 000 Ω or more.

Sinusoidal Waveforms

Sinusoidal waveforms will be generated if a resonant circuit is connected across the terminals P and Q. The low absolute value of the negative resistance can be useful in several ways: The resonant circuit may be tapped very low, resulting in a small sensitivity for capacitance variations. It is also possible to use a high-impedance circuit and a very small direct anode current; e.g.,

0·1 mA. If a low-impedance resonant circuit is employed, oscillations will build up and die out very rapidly as the anode current is switched on and off. This is especially valuable in super-regenerative reception of wide frequency bands. The above-mentioned hexode may be employed in a circuit shown in Fig. 16 with voltage sources and separating capacitors omitted. The quenching frequency is generated by the negative resistance between T and S-R, which is about 2 000 Ω; the h.f. oscillations are generated by the negative resistance between T-S and R, which is about 100 Ω when the anode current is switched on.

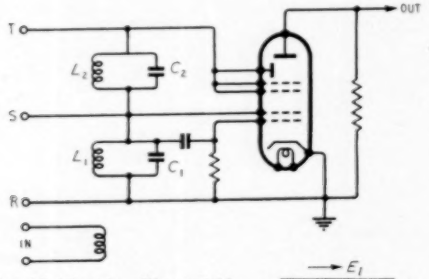


Fig. 16 (above). *The variable-mu valve employed for super-regenerative reception of broad bands.*

Fig. 17 (below). *An RC generator of sinusoidal waves.*

Fig. 18 (right). *Very fast spontaneous switching of the current in a s.e. valve.*

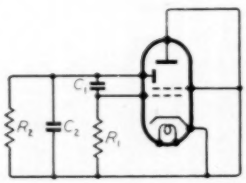


Fig. 17 shows an RC generator of sinusoidal vibrations. In this $-\delta I_d/\delta E_{g1}$ should be a little larger than

$$\frac{1}{R_2}+\frac{1}{R_1}\left(1+\frac{C_2}{C_1}\right).$$

The frequency is given by

$$\omega^2=\frac{1}{R_1R_2C_1C_2}.$$

Generation of Abrupt Waveforms

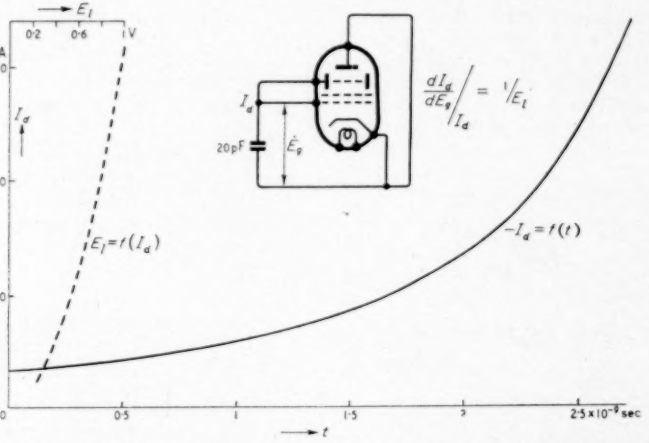
Fast non-sinusoidal waveforms can also be generated by one valve without the aid of a transformer.[10] The dynamic negative resistance between the terminals P and Q in Fig. 15 will give rise to a very rapid increase of the voltage generated spontaneously when dynode current is allowed to flow. This is especially due to the high value of $\dfrac{\delta I_d}{\delta E_{g1}}\Big/ I_d$.

In a s.e. valve with one stage of multiplication the reciprocal value E_l of this quantity is about half that of a normal valve. A capacitance C_p (partially due to stray effects) connected across the terminals P and Q of Fig. 15 (a) will charge according to the equation

$$\frac{dE_{g1}}{dt}=\frac{I_d}{C_p}.$$

If we define $\dfrac{\delta I_d}{\delta E_{g1}}=\dfrac{I_d}{E_l}$ it follows that the time in which the current I_d rises spontaneously from I_1 to I_2 is given by

$$t_2-t_1=C_p\int_{I_1}^{I_2}\frac{E_l}{I_d^2}\,dI_d.$$



It appears that this time is proportional to E_l. In Fig. 18 the fully-drawn line shows an example of the calculated course of a spontaneous charge of a capacitance of 20 pF connected across the terminals P and Q if the dependence $E_l=f(I_d)$ is given by the dotted line relating to a one-stage valve. This charging time is so short as to be of the same order as the transit time of the electrons or the period of the circuit. It is much smaller than is usually obtained with conventional multivibrators. In valves with

several stages E_l may have values about one-half or one-third of those shown. The time t_2-t_1 is especially important in triggers and multivibrators since it is a measure of the switching time from a low-current position to one of high current and vice versa.[11]

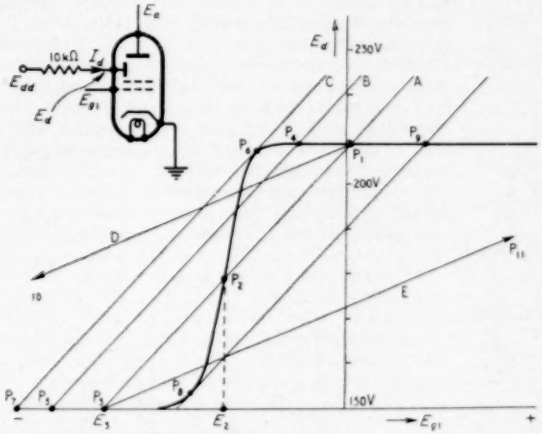
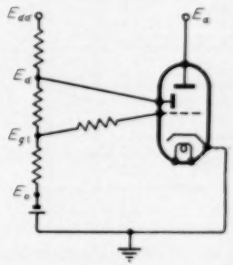


Fig. 19 (left). *This measured characteristic of a s.e. valve is used for the synthesis of various commutating circuits.*

Fig. 20 (below). *Simple bistable circuit. It needs polarized trigger pulses for the transitions.*



Triggers and Non-sinusoidal Waveforms

Fig. 19 shows a characteristic $E_d = f(E_{g1})$ of a valve EFP60 at $E_{dd} = 150$ V, $E_a = 250$ V when a resistance of 10 000 Ω is inserted in the dynode lead. This curve will be used as a basic characteristic for the synthesis of monostable and bistable triggers and astable generators. When the cathode current begins to flow E_d will rise (I_d is negative), but it cannot rise higher than to about 210 V, which corresponds to about 8 mA secondary current, because 40 V between anode and dynode are needed to draw this current to the anode.

If E_{g1} is tapped from a suitable potentiometer between the dynode and a negative voltage E_o, line A may show the dependence $E_{g1} = f(E_d)$. The intersections of these two functions indicate possible states of equilibrium. P_1 and P_3 correspond to stable equilibrium, P_2 to unstable as a small deviation will cause the operating-point to shift to P_1 or to P_3. This bistable circuit (Fig. 20) can be used as a scaler, but it has the disadvantage that it needs pulses of opposite polarity for the two transitions. It is interesting to note what happens if line A is displaced to the left. Line B which is parallel to A has two stable states, but the transition from P_4 to P_5 will release potential energy. Only a small pulse suffices to initiate this transfer, but for the opposite direction a much larger pulse is necessary. So P_4 could be called a metastable state. If position P_4 is realized and line B is displaced further, finally P_6 will be reached and at that moment the operating point will jump to P_7. Only one position is then stable.

If the control grid is tapped from the same potentiometer but a not too small capacitance is inserted in the grid lead and this grid is connected to a voltage source via a high resistance, a monostable trigger or an astable generator can be realized (Fig. 21). If the grid voltage is made E_3, line A represents the dependence $E_{g1} = f(E_d)$ for rapid variations. A suitable pulse will transfer the operating point from P_3 to P_1, but this is a quasi-stable state, E_{g1} having a tendency to run back to E_3. The operating point will move from P_1 via P_4 to P_6, then jumping to P_7 and after some time reaching P_3 again.

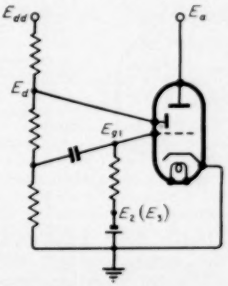


Fig. 21. *Multivibrator employing a s.e. valve.*

This one-shot multivibrator action will be changed into continuous generation by changing E_{g1} to E_2. Now the operating point will move from P_1 to P_6 in an attempt to reach $E_{g1}=E_2$; it will jump to P_7, and again it will try to reach $E_{g1}=E_2$, but it will jump from P_8 to P_9 and so on. It is easy to calculate from the circuit data and the valve characteristic the frequency of this square-wave generator. The anode may be used as an output electrode.

The bistable circuit corresponding to line A has no preference for one of the two stable positions.

If a capacitor C_1 is placed between dynode and control grid (Fig. 22) lines D and E will apply to rapid variations. If position P_1 is realized it will be metastable with respect to the quasi-stable point P_{10}. Any small pulse of short duration will initiate the transition P_1—P_{10}. After some time, depending on the charging time of C_1, the operating point is so close to P_3 that it is metastable with respect to some point near P_{11}. The same small pulse of short duration will now initiate the transition P_3—P_{11}. In this way a scale-of-two circuit is obtained which does not need polarized trigger pulses. The transition

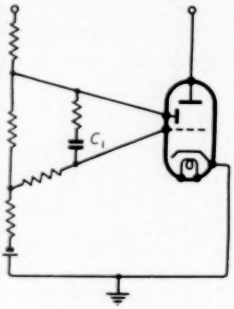


Fig. 22. *Bistable circuit. A short time after each transition the operating position becomes metastable with respect to the other position. The trigger pulses need not be polarized.*

P_3—P_{11} will result in a much higher pulse of I_d and I_{g2} than the opposite transition, and this pulse can be used for initiating the next stage. To prevent high-frequency oscillations a resistor should be connected in series with C_1.

Dynode and Anode Follower

Property (*f*) makes a secondary-emission valve suitable for the purpose of a follower that can be switched on and off. If in Fig. 23 R_d and R_a are not too low when the cathode current is switched on by changing the control-grid voltage, the anode voltage will drop till it is a little higher than the

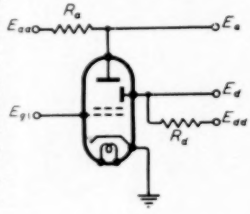


Fig. 23. *Electronic switch employing a s.e. valve.*

dynode voltage and will follow the variations in dynode voltage. Also the dynode voltage will follow the anode voltage. Thus the valve functions like a relay that can be switched on and off. This circuit, originally proposed by Douma, has been applied in the demodulator of an installation for multiplex-pulse modulation. Each of the eight channels was switched in successively for a short time and during that time the dynode followed the anode voltage.[12]

Wideband Amplification

It is not generally realized that the number of s.e. valves necessary for a wideband amplifier is smaller than it seems at first.

Let us suppose a s.e. valve having a wideband figure of merit twice that of a corresponding normal valve. If in a wideband amplifier 80 db overall gain is obtained with eight normal valves the mean gain per valve is 10 db. One is inclined to think that the mean gain per s.e. valve will be 16 db, thus five s.e. valves will be necessary. But in practice four of these valves may give more than 80 db amplification at the same bandwidth, since the number of interstage coupling circuits is also smaller, so that each coupling circuit can be made narrower to give the same overall bandwidth. In a stagger-tuned amplifier or with transitionally-coupled circuits, each valve

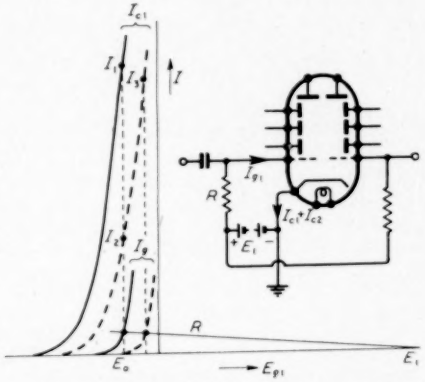


Fig. 24. *Stabilization of the cathode current by a high resistance R and a positive voltage E_1.*

having a wideband figure of merit twice that of another valve will not give much more than 6 db increase in gain, especially if the gain per stage is not very small, but a smaller number of stages will result in a smaller overshoot. In a distributed amplifier with push-pull output Moody and McLusky[13] replaced fourteen 6AK5 valves with a total gain of 30 by four EFP60 valves giving a voltage gain of 65.

Bias Voltage Adjustment

Something has already been said about the mean voltage adjustment of the control grid of s.e. valves in the article mentioned.[1]

In a circuit with a multiple-stage s.e. valve the anode direct current should be fed back to the control-grid voltage in order to stabilize the anode

current when the secondary emission changes. A rather high anode resistance and a potentiometer between the anode and a source of negative voltage with respect to the cathode are necessary. The control-grid voltage is tapped from the potentiometer. When the secondary-emission factor does not change much it is also possible to connect the control grid via a resistance of the order of $10^6\ \Omega$ to a source of positive voltage (Fig. 24). Variations in the difference of the work-functions for the control grid and the cathode will then be eliminated by a change in the voltage drop of the grid resistor. In Fig. 24 two values of the work-function of the grid are considered, one resulting in the fully-drawn lines of I_c and I_g, the other resulting in the dotted lines. With constant grid voltage E_o the corresponding cathode currents are I_1 and I_2. If the control grid is connected via a resistor R to a voltage E_1 the grid voltage will be adjusted automatically to such values that now the cathode currents are respectively I_1 and I_3. In many cases the load resulting from the grid current will not be of any consequence. This adjustment is especially useful in push-pull valves with a common cathode lead where it is not possible to adjust the two parts of the cathode current separately.

Acknowledgment

The author wishes to thank Dr. J. L. H. Jonker for his valuable advice in the preparation of this paper. Dr. Jonker and many others have made substantial contributions. The author appreciates particularly the assistance of Messrs. D. Abbenes, J. D. de Hartog and F. Vlugt.

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NATIONAL PHYSICAL LABORATORY

Open days for industrial representatives are to be held on 28th and 29th May, at the National Physical Laboratory, Teddington. It will be open on both days from 10.30 a.m. to 5.30 p.m., and luncheon and tea will be obtainable on the premises.

Accredited representatives of industrial organizations and those interested should apply for tickets to the Director at the above address not later than 8th May. They should indicate on which of the two days they would prefer to visit the Laboratory.

BRITISH INSTITUTION OF RADIO ENGINEERS

The Institution's Festival of Britain Convention is divided into six sections. Session 1 is on "Electronic Instrumentation in Nucleonics," on 3rd and 4th July, and Session 2 covers "Valve Technology and Manufacture," on 5th and 6th July. Both will be held at University College, London.

The third and fourth sessions will be held at University College, Southampton, and are on "Radio-communication and Broadcasting" and "Radio Aids to Navigation," on 24th and 25th July and 26th and 27th July respectively.

Session 5 is "Television Engineering" and includes the Clerk Maxwell Memorial Lecture by Professor G. W. O. Howe. It will be held at King's College, Cambridge, on 21st to 24th August.

Session 6 is "Audio Frequency Engineering." It will be at The Richmond Hall, Earls Court, London, on 4th to 6th September.

The convention will include discussion meetings as well as main papers. Applications for meeting tickets and for reservation of accommodation for the out-of-London sessions should be made before 30th April to the Secretariat of the Institution at 9 Bedford Square, London, W.C.1.

SOUTH BANK EXHIBITION

During the Festival of Britain, communications will form an important part of the Exhibition at South Bank, London. The Exhibition opens on 3rd May and the telegraphy section will show important historic apparatus as well as the latest pattern teleprinters and facsimile apparatus in operation. "Telephones and Cables" exemplify the operation of Britain's telephone network, the polyethylene coaxial cable, and the submarine repeater.

"Radio Communications" will include a working model of a time-sharing pulse multiplex system while in the Radar section there will be a 4-ft working model of a magnetron in which illuminated tracks will show the paths of electrons and h.f. currents. There will also be a high-definition working exhibit of a harbour-type radar installation arranged to display a radar map of the Thames from Lambeth Bridge to Blackfriars.

Working diagrams will be arranged to explain the operation of television and there will be a large range of television apparatus on view. In the Telecinema large-screen projection television will be demonstrated and also stereoscopic colour films with a four-channel sound system to provide also stereophonic sound. Sound recording will have a section to itself as also will sound broadcasting. Here it is expected that some of the results of the a.m. and f.m. trials from Wrotham will be displayed.

SYSTEMS OF UNITS AND NOMENCLATURE

THE *Revue Générale de l'Electricité* of June 1950 contains a communication from Giorgi, who, 49 years ago, first suggested the system of units which is associated with his name. As his letter contains some adverse criticism of subsequent developments we thought that readers would be interested in it, and we, therefore, give a translation of it :—

1. It was in 1901 that I proposed the system of rational units of electromagnetism as a new system absolutely suitable to replace the two c.g.s. systems and the practical system, which was not completely absolute. My system was used sporadically by several authors, either entirely or with secondary modifications. Finally, the I.E.C. at the meetings at Scheveningen and Brussels in 1935, recognized it officially and discussed its adoption. These discussions were confirmed at the subsequent meeting at Torquay in 1938. The actual question is the sanctioning of the system by the legislation of all the nations, following the initiative of the International Association of Physics and the International Bureau of Weights and Measures. In the course of the discussions several ambiguities of nomenclature were committed, which have been repeated by authors, and it is necessary to draw attention to them in order to re-establish accuracy.

2. In the first place, the system proposed by Heaviside in 1901, has been called the Heaviside-Lorentz system. The sole object of this system was to put the factor 4π in its right place, so as to be able to use 'rationalized' formulae, but it did not envisage the elimination of other more serious 'irrationalities,' one of which was the separation of the electrostatic and the electromagnetic units. Heaviside proposed to change the ampere, volt, ohm, etc., by multiplying or dividing their values by 4π, $\sqrt{4\pi}$, etc., which would have upset everything and would never have been adopted by electrical engineers : his proposal was, therefore, dead before it saw the light of day. It is a mistake to link the name of Lorentz with this proposal ; he never had occasion to use any particular system of units, nor did he agree with Heaviside's suggestion ; he simply used rationalized equations as many other authors did, and these were as much in accord with my system as with that of Heaviside.

3. In the second place, it has been said repeatedly that my system was based on the metre, kilogramme, second, and *ohm*. It was Kennelly who interpreted my proposal in this way. The essence of my proposal was the recognition that the introduction of a fourth fundamental unit would eliminate the derivation of the electrostatic and electromagnetic systems ; but I never stated that the ohm should be the fourth unit. My opinion has always been that the whole collection of practical electrotechnical units, related to each other by well-known conventions, should be regarded as a fourth fundamental unit.

4. In the third place, one has applied the names 'electrostatic' and 'electromagnetic' to the systems with four fundamental dimensions based respectively on $[LMT\epsilon]$ and $[LMT\mu]$. But, the names ought to be applied in accordance with their original significance. Now, the creation of the two classical systems dates from the paper by Maxwell and Jenkin in 1863, and there it is clear that for these two authors, and also for Maxwell in his " Electricity and Magnetism," the fundamental idea was to regard ϵ_o or μ_o as a pure numeric without physical dimensions, and to base the theory of dimensions and units solely on the three fundamental mechanical units and not on four units. The classical authors who followed them, including Heaviside, adopted the same point of view.

Now, however, we have different ideas and, following the principles that I supported in 1901, we find that the systems with four fundamental dimensions are preferable and more natural ; but we have no right to say that the two systems based on three fundamentals were illogical.

The two systems which regard ϵ_o or μ_o as a fourth fundamental unit could be called neo-electrostatic or neo-electromagnetic. It is to be hoped that they will soon be forgotten and that the units derived from the metre, the kilogramme, the second, and the usual electrotechnical units will be employed by physicists as they are by electrical engineers.

5. In the fourth place, one is not justified in reserving the name 'absolute' for electrical units which are exact multiples of the c.g.s. units. Any system is absolute in which the units are derived in a coherent and regular way from a few fundamental units. In 1863 one thought that there must be three fundamental units because it was believed that all physical phenomena could be explained mechanically. Now it is agreed that in the derivation of the electric units and dimensions a fourth fundamental magnitude of an electrical nature must be employed ; the word 'fundamental' implies that the magnitude of the unit is arbitrary. In principle then, if one chooses arbitrarily the four fundamental units, and deduces the others organically from them, the resulting system has the right to be regarded as absolute.

For example, one could take the metre, the kilogramme, the second and the unit of resistance of W. Siemens (a column of mercury 1 metre long and 1 square millimetre cross-section at 0°C), or one could take as the fourth unit the e.m.f. of the Weston standard cell, and one obtains systems which could be regarded as absolute. The ohm defined as equal to 10^9 c.g.s.e.m. units is no more absolute than the Siemens unit if this is chosen as the fundamental unit. It would be reasonable to refer to the multiples of the c.g.s.e.m. units as electromagnetic ohms and amperes without the qualification 'absolute'.

6. In the fifth place, it is due to a heritage from the past that one regards as *absolute measurements* determinations of the ohm, ampere, etc., made with the object of stamping them as exact multiples of the c.g.s. units. When one weighs with extreme accuracy a cubic decimetre of water, should one say that one is determining the absolute kilogramme, or that one is determining the density of water ? The latter is the more natural. Similarly the so-called absolute determinations of the electric units are really measurements of ϵ_o or μ_o in terms of certain values of the ohm or volt with which one works. It is to our interest to recognize this and to bring out clearly the distinction between measurements made by electromagnetic methods and those made by electrostatic methods.

7. I would like now to make a statement of a personal

Since making this translation we have learnt with regret that Giovanni Giorgi, Professor of Mathematics and Mechanics at the National Academy of Sciences, Rome, died on 20th August, near Leghorn. He was in his 80th year.

nature. In the recent official publications the system that I have proposed has been called the M.K.S.A. system, omitting any reference to my name. Now, the designation 'Giorgi system' was unanimously adopted by the international conferences at Scheveningen and Brussels in 1935, and at Torquay in 1938. The designation 'M.K.S. system' that I had formerly used was turned down because it gave the impression that it was a system based on three fundamental units, which was only justified in connection with mechanical units. The addition of the A (ampere) avoids this difficulty; and the specification is completed by the statement that the new ampere (improperly called absolute) is that current which, when flowing through two filiform straight conductors of infinite length separated by 1 metre, causes a mutual force of 2×10^{-7} m.k.s. units per metre of length. All this is theoretically sound and suitable for fixing one's ideas, but one must not think that it is possible to carry out this measurement with the degree of precision necessary in the determination of standards.

At the International Bureau of Weights and Measures and at the six large national laboratories, electrical standardization will continue to be based on the manganin ohm and the Weston standard cell. As the result of recent researches the new values of the ohm and volt have been determined so as to bring them into as close agreement as possible with their original definitions and consequently with the new definition of the ampere. The accuracy attained is about one part in 100,000, but the actual standards can be reproduced with an accuracy from 10 to 50 times as great.

We consequently find ourselves in the same condition as if the metre had received a double specification, theoretically as a fraction of the length of the terrestrial meridian, and practically by the material standard which is supposed to represent it. We can look forward to something similar happening in the future, and the question will arise whether the standards should be touched up or whether the theoretical definition should be abandoned. It would be as well if we prepared ourselves for this situation.

G. Giorgi.

BIBLIOGRAPHIC NOTES

The literature relating to my system of units is very abundant. My original communication made to the electrotechnical congress in Rome in October 1901 was printed under the title "Unita razionali di elettromagnetismo" in *Atti dell'Associazioni elettrotecnica italiana*, 1901, Vol. 5, p.402–418, and reproduced and translated in several journals.

One can consult also my two articles: "La métrologie électrique classique et les systèmes d'unités qui en dérive." Examen critique. *Revue générale de l'électricité*, 10th October, 1936, p.459–468—"La métrologie électrique nouvelle et la construction du système électrotechnique absolu M.K.S."—Ibid 24th July, 1937, p.99–108.

The text of my original communication is also reproduced in my book "Verso l'elettrotecnica moderna," published in Milan in 1949. This contains also several other papers on the same subject and a complete bibliography.

One will find other information on physical units in "Métrologie générale," a manual by Denis-Papin and J. Vallot, Paris 1948, and in particular on my system in "Memento des Unités Giorgi," by Denis-Papin and Kaufmann, Paris 1949.

Tables of the relative values of the old and new electric units are given in my latest work, "Dati e valori per la fisica e l'elettrotechnica," Milan, 1950.

See also the special number "Unités et Mesures" supplement to *La Nature* December 1949, and "L'introduction du système d'unités Giorgi" (report of the Technical Committee) in the *Bulletin de la Societe suisse des Electriciens*, 23rd July, 1949, p.462.

In connection with the above letter from Giorgi, it is interesting to note that 10 years before his 1901 article, viz. in *The Electrician* of 31st July, 1891, an article entitled "Practical Electromagnetic Units," by Prof. John Perry, had been published. It was communicated by Dr. R. T. Glazebrook in accordance with the author's wishes. It had been written some years before 1891, and had been brought forward at various meetings of the Electrical Standards Committee of the British Association.

We propose to give a few extracts from the article:—

"Men who use the ohm, ampere, and volt in their electric calculations object to the conversion of these to C.G.S. units when making calculations on the magnetic circuit of the dynamo machine or of transformers and other electromagnetic contrivances. It is with great diffidence that I make the following suggestions".....

...."I would suggest that the practical unit of magnetic flux (or induction or force) be 10^8 C.G.S. units, and that it receive a name. That the magnetic permeability of air shall no longer be assumed to be unity, but, in the practical system of measurement, be tabulated like the permeability of any other substance—the permeability of air will be $4\pi \times 10^{-9}$]—and that in future no substance shall have unit permeability. That the unit of total magnetomotive force in a magnetic circuit be one ampere-turn. The unit of magnetomotive force gradient would be one ampere-turn per centimetre. It will follow that:—

I A wire one centimetre long, moving at 1 cm per second across unit field, generates an E.M.F. of 1 V.

II If a wire 1 cm long conveys 1 A, the power used (or developed) in moving it across the unit field at 1 cm per second is 1 W.

III A magnetomotive gradient of one ampere-turn per centimetre produces unit induction (magnetic flux or force) per square centimetre if the permeability is 1.

IV Change of induction (magnetic flux or force) at the rate of unit per second produces 1 V per turn of wire.

The integral of the magnetomotive force all round any elementary solenoid in a magnetic circuit is exactly the number of ampere-turns."

Thus we see that 60 years ago Professor Perry advocated the use of a rationalized practical system, which only differed from the most up-to-date present-day system by his adherence to the centimetre as the unit of length. As is well known, the unit of mass in such a system must be 10 tons.

It is interesting to note that the same issue of *The Electrician* contained articles by Oliver Heaviside, Silvanus Thompson, J. A. Fleming, and Gisbert Kapp, but all on different subjects.

G. W. O. H.

CORRESPONDENCE

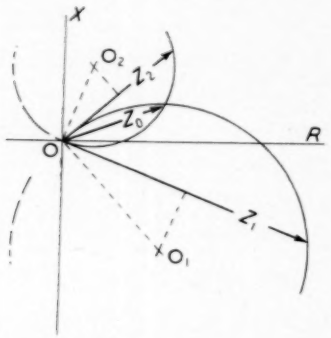
Letters to the Editor on technical subjects are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Impedances in Parallel

SIR,—Mr. C. R. G. Reed's letter in your January 1951 issue prompts me to offer another graphical method of finding the resultant of two impedances in parallel. The construction is based on the following theorem:

The resultant impedance vector of two impedances in parallel is the common chord of two circles, each of which is tangent to the vector of one impedance at the origin and has the vector of the other impedance as a chord.

Given Z_1 and Z_2 as vectors from an origin O. At O erect a perpendicular to Z_2 meeting the perpendicular bisector of Z_1 at O_1. Similarly, find O_2 as the intersection of the normal to Z_1 at O and the perpendicular bisector of Z_2. Draw circles through O with centres at O_1 and O_2. The intersection of these circles gives the required impedance $Z_0 = Z_1Z_2/(Z_1+Z_2)$.



The proof lies in deriving analytic equations for the two circles, and solving them simultaneously. One pair of roots is zero. The other gives the real and imaginary components of Z_0.

Submarine Signal Division, LAURENCE BATCHELDER.
Raytheon Manufacturing Co.,
Massachusetts, U.S.A.
8th February, 1951.

SIR,—The correspondence from C. G. R. Reed on this subject published in the January issue of *Wireless Engineer* has been read with interest. May I draw your attention to an alternative simple graphical solution to the problem, which also does not appear to be well known, and which has been described by C. F. Tyrrell in *Bulletin of Electrical Engineering Education*,* No. 5 p. 22, November, 1950.

F. A. BENSON.

Dept. of Educational Engineering,
University of Sheffield.
24th January, 1951.

* This Bulletin is produced by the College of Technology, Manchester.

Synthesis of $2n$-Terminal Networks

SIR,—Several recent articles[1,2,3] have dealt with the synthesis of passive $2n$-terminal networks with prescribed impedance or admittance matrices. By considering the *scattering* (or *efficiency*) *matrix*, already used in similar researches[4,5], we have obtained more general results and have solved the problem of finding all $2n$-terminal networks equivalent at all frequencies to a given one. So far, a solution of the general equivalence problem was only known for purely reactive networks[6].

Our results are briefly described below and will be proved in detail in a forthcoming paper.

1. A matrix S is the scattering matrix of a passive $2n$-terminal network, if, and only if, (a) S is symmetrical, (b) the elements of S are rational real functions of $p=\alpha+j\omega$, analytic in the right half-plane including the imaginary axis, (c) the matrix E_n-SS^*, where E_n denotes the unit matrix of order n and S^* the complex conjugate of S, is positive definite or semi-definite on the imaginary axis.

2. If E_n-SS^* has rank $h<n$, the $2n$-terminal network of matrix S is realizable as a reactive $2(n+h)$-terminal network closed on h unit resistances. The scattering matrix of the reactive network is obtained by bordering S symmetrically with h rows and columns, so as to obtain a matrix Σ, unitary on the imaginary axis and satisfying the requirements of paragraph 1.

3. All the unitary matrices Σ containing S as submatrix are of the form $N'\Sigma_oN$, where Σ_o is a particular minimal matrix and

$$N=\begin{pmatrix} E_n & 0 \\ 0 & T \end{pmatrix}$$

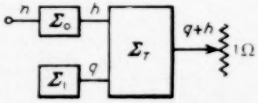
with an arbitrary matrix T of order h, unitary on the imaginary axis and fulfilling conditions (b) of paragraph 1. The minimal matrix Σ_o is found by canonic reduction of the Hermitian form associated with E_n-SS^* and by factorization of the diagonal elements of the reduced form.

4. Physically, transforming Σ_o into Σ means connecting in tandem with the $2(n+h)$-terminal reactive network Σ_o a $4h$-terminal reactive network of scattering matrix

$$\Sigma_T=\begin{pmatrix} 0 & T \\ T' & 0 \end{pmatrix}$$

where T' denotes the matrix T transposed. Any $4h$-terminal network having such a scattering matrix is *transparent* to a set of h unit resistances. This arbitrary transparent network plays here the same role as the arbitrary all-pass in 4-pole synthesis, and the minimal network Σ_o corresponds to the minimum phase-shift network of 4-pole theory.

5. Networks of prescribed S matrix containing more than the minimum number h of resistances are realized by constructing unitary matrices of order $n+h+q$, with an arbitrary positive integer q. Such matrices, having S as submatrix, are all of the form



$$N'\begin{pmatrix} \Sigma_o & 0 \\ 0 & \Sigma_1 \end{pmatrix}N$$

where Σ_1 is an arbitrary unitary scattering matrix of order q, and N is the matrix used in paragraph 3, but with a matrix T of order $h+q$.

6. Once a $2n$-terminal network has been reduced to its canonic form [i.e., to a minimal $2(n+h)$-terminal reactive network Σ_o closed on h resistances] all equivalent $2n$-terminal networks are obtained by the following procedure: (a) add an arbitrary $2q$-terminal reactive network Σ_1 closed on q additional resistances and unconnected to Σ_o, (b) insert an arbitrary transparent $4(q+h)$-terminal network Σ_T linking to each other the $q+h$ resistances on one hand and the reactive network with unconnected parts Σ_o and Σ_1 on the other; this gives the network sketched in the figure, (c) transform the reactive $2(n+h+q)$-terminal network of the figure (without resistances) into any equivalent form by known methods.

V. BELEVITCH.

Brussels, Belgium.
12th February, 1951.

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NEW BOOKS

Micro-wave Measurements

By H. M. BARLOW, B.Sc.(Eng.), Ph.D., M.I.E.E., and A. L. CULLEN, B.Sc.(Eng.), A.C.G.I., A.M.I.E.E. Pp. 399 +xvi. Constable & Co., Ltd., 10 Orange Street, London, W.C.2. Price 30s.

With the big advances that have been made in the generation and application of centimetre waves has been built up the solid foundation of measurement technique which was necessary to the advancement of the subject.

Measurements at centimetre wavelengths require techniques which differ considerably from those used at longer wavelengths and in many cases are more sophisticated. In the design of equipment for centimetre wavelengths less can be done by design data or rule of thumb than in conventional radio practice, and measurements are much more necessary. Comparatively little has been written on the subject, so the appearance of a book with the title "Micro-wave Measurements" is to be welcomed, particularly one which fulfils its task so competently. "Micro-wave" has its generally-understood meaning of wavelengths for which waveguides and resonant cavities are most appropriately used, and the book confines itself almost entirely to measurements involving these.

The range can be seen from the chapter titles—Measurement of Wavelengths and Frequency, Standing-Wave Measurements, Matching and Transmission Systems, Measurement of Power, Attenuation and Q-factor, Electrical Properties of Materials, Receiver Measurements, Transmitter Measurements, Measurements on Aerials, together with three introductory theoretical chapters. The treatment is fairly elementary, making no attempt to be exhaustive, and keeps mainly to the basic methods. In so doing it gives the reader a very fair picture of why these many measurements are so essential, and concentrates on providing a sound theoretical basis for them, rather than going into details of instrument design.

The main criticism which the reviewer has is on the lack of information concerning the range over which the different instruments operate and the accuracy which might be expected from them. This is very noticeable in the chapter on power measurement where, in view of wide discrepancies which have existed and in some cases still exist, a critical appreciation would have been valuable. Again, when dealing with standing-wave measurements it would have been useful to compare the order of accuracy given by the precision instrument with that of the simple instrument which is satisfactory for many purposes. As most measuring equipment has to be constructed by the user rather than bought, details of effects of constructional inaccuracies are important.

Measurement of standing-wave ratio by means of a directional coupler is a method which is rapidly increasing in popularity, and as such deserves more than to be dismissed in a few lines as a rather rough field method.

A well-chosen collection of references is given at the end of each chapter. The book is printed on good paper, with wide margins, and altogether is an attractive publication.

H. R. L. L.

Father of Radio

By LEE DE FOREST. Pp. 502+x, with numerous illustrations. Wilcox & Follett Co., Chicago. Price $5.

This is the title which Dr. de Forest with characteristic modesty gives to his autobiography, but to avoid any misunderstanding it should be stated that the word Radio is probably used in a restricted sense to signify broadcasting and not wireless telegraphy in general, and in this restricted sense there is much to justify the claim. Before opening the book we learn from the paper cover that there are 14 historic firsts to the credit of de Forest; viz., wireless transmission overland, 1904; between moving train and fixed station, 1905; three-electrode valve, 1906; broadcast, 1907; transmision of voices without wires, 1907; radio knife in surgery, 1907; broadcast of grand opera, 1910; successful telephone amplifier, 1912; feedback or oscillator circuit, 1912; use of oscillating valve in broadcasting, 1915; electronic musical instrument, 1915; electromagnetic phonograph pick-up, 1916; radiotelephone from airplane in flight, 1916; and theatrical presentation of sound-on-film talking motion-picture, 1923. The book concludes with a list of 207 patents, 40 of which were taken out before the end of 1906.

In the preface the author expresses the hope that the frank revelation of his own struggles, disappointments, and successes may encourage others to embark on a similar career of discovery and invention. It certainly is a frank revelation and its personal character makes it intensely interesting. It is divided into 51 chapters and—what will be a surprise to many people—an appendix containing poems with such titles as California Twilight, Regret, Dream Rose.

In 1898, at the age of 25, he gained the Ph.D. of Yale and joined the Western Electric Co. It is enlightening to read "and there now I began a serious systemized search through *Science Abstracts*, *Wiedemann's Annalen*, *Comptes Rendus*, and other physics journals." Another quotation from his diary at this time is, "And so, while the week nights must be diligently given to science and my work, one evening I owe to music. The Sundays I must give to the poets and philosophers, to the deep and true thoughts."

He soon left the Western Electric Co., and started the American de Forest Wireless Telegraph Co. "From the start I had the one aim in view, to make my name at least rank with that of Marconi. Merit alone could win in this matter." In February, 1902, he wrote in his diary, "I shall move all heaven and earth to put in at once a broad fundamental patent on *telephony* without wires by

Hertzian waves." This was five years before the invention of the triode. In Chapter 19 we get to 1907 and the 'conception of the audion': that is, the invention of the three-electrode valve. Chapter 22 entitled 'Radio invades Europe' describes a visit he paid in 1908 to demonstrate his radio-telephone system and also his 'radio knife'.

In 1912, his financial affairs having crashed, he was engaged by C. F. Elwell to work in the laboratories of the Federal Telegraph Co., at Palo Alto, California, and it was there that feed-back and the valve oscillator were invented. The following year, however, financial affairs having been adjusted, he was back in New York, experimenting and fighting patent litigation. In 1916, using a valve oscillator, the broadcasting of music from gramophone records was carried out from a 125-ft tower on the factory roof in New York, but the federal authorities stopped it because of interference with commercial communications. He was informed that "there is no room in the ether for entertainment." Several chapters are devoted to de Forest's work in connection with talking pictures and television. He remarks that it is perhaps fitting that he has been called the "Grandfather of Television."

He bewails the low level of American broadcast material. He says, "But his British brother has had a different upbringing. Under government sponsorship, radio appeals there to the higher intelligence, realizing its fine mission to elevate, and not degrade. This is anathema to America's broadcasters . . . we might learn much from England . . . but the consistently worsening quality of our *average* American radio programmes, even without their crass and blatant commercialism, is a saddening symbol, a symptom which should be evident to every thinking mind . . . Alas, that the tycoons of radio are content to sell our listening birthright for such a stinking mess of pottage!"

In view of the long-draw-out patent litigation with Marconi, Armstrong, Fleming and others, it is pleasant to note that he salutes Armstrong of f.m. fame, and of Marconi he says that his pioneer work and daring vision well entitle him to be called "the father of the wireless telegraph." Of Sir John Fleming, as he calls him, he says that " he was unregenerate at the age of 92, and having married a young opera singer at 84, he lived to the ripe old age of 95, and never yielded in his firm conviction that he was radio's true inventor!"

The above will give a general idea of the character of the book, which we read from cover to cover, and found very interesting. G. W. O. H.

Radio Communication at Ultra High Frequency

By JOHN THOMSON, M.A., D.Sc., F.Inst.P. Pp. 203 + xix, with 99 illustrations. Methuen & Co., Ltd., 36 Essex Street, London, W.C.2. Price 21s.

In this book the term 'ultra-high frequency' is used to denote frequencies greater than 100 Mc/s. The author is careful to explain this in his introduction where, although he deprecates the vagueness of the expression, he says that "It has been used in the title of the present volume simply because there is no better term in common use."

The first chapter is devoted to v.h.f. circuits and in it are given the main facts about parallel wires, concentric lines and waveguides, particular emphasis being laid on the resonant condition. Chapter 2 covers valves; it starts by explaining why ordinary valves are unsuitable at v.h.f. and goes on to describe the disc-seal triode, the klystron, the magnetron and the travelling-wave valve.

Chapter 3 has the title 'Power Amplifiers, Frequency Multipliers and Oscillators' but is given the running heading of 'Power Units.' While this may be a literally correct abbreviation of the title it is a little misleading, because it will make most people think of h.t. supply units. The major part of this chapter is devoted to the klystron and its characteristics are clearly explained.

Chapter 4, "Receiver Input Circuits," is by a different author—P. E. Trier, M.A. It is a long one, 47 pages, and contains a very comprehensive and well-written account of noise factor. The various sources of noise are described in turn with the methods of computing them and the measurement of noise factor is also briefly treated.

Modulation techniques are discussed in Chapter 5 and the two concluding chapters cover frequency-control and communication systems.

Quite a large part of the book is purely descriptive but the author does not hesitate to use mathematics where necessary. It would be wrong to describe the book as a mathematical one and yet partial differential equations and Bessel functions do appear in it. Probably two-thirds of the book can be fully understood with the aid of little more than simple algebra. To take full advantage of the remaining one-third however, the reader must be better equipped. Except perhaps in Chapter 1, which is really a refresher course in v.h.f. circuits, the explanations are full and clear. The book covers the subject adequately and should be useful to both students and engineers.

It should, perhaps, be made clear that although the magnetron is described in the book it is not treated in any great detail. This is because its application is mainly to radar and not to communications. It is the klystron which, in its various forms, receives the most attention. W. T. C.

Electrophysiological Technique

By C. J. DICKINSON, B.A., B.Sc.(Oxon). Pp. 141 + vii, with 60 illustrations. *Electronic Engineering*, 28 Essex Street, Strand, London, W.C.2. Price 12s. 6d.

In his preface the author states that his aim in producing this book has been "the editing of an ever-growing library of information about different techniques, and its presentation in a collected and practical form for quick reference in the laboratory." He has, in fact, compiled what may conceivably be termed a 'notebook' which covers mainly the forms of circuit used in electronic apparatus.

After his introduction, in which some of the requirements are briefly described, the author goes on to discuss valve standardization and gives a short list of valve types. This covers most of the electrophysiological requirements and represents the valves which are used for illustrative purposes in later diagrams. Cathode-ray tubes are later treated and there is a chapter on power supplies.

Trigger circuits are dealt with in 5½ pages and time bases in eight. As might be expected, therefore, the treatment is cursory and only a few types are discussed. Biological amplifiers have 20 pages and there are a further six pages on d.c. amplifiers. There are then short chapters on Electrodes, L.F. Oscillators, Stimulators, Time Marking and Measurement, Production of Mechanical Movement, Display and Recording of Mechanical Movement, Pressure and Volume Registration, Measurement and Control of Heat and Light Measurement. The book concludes with a bibliography, diagrams of valve-base connections and an index.

The treatment is generally very brief and there is no attempt at a comprehensive discussion of the pros and cons of the various alternative ways of achieving a required result. Generally, one or two only of these ways are referred to and even these are not fully described. The reader must be prepared to turn to the original papers, quoted in the bibliography, for such description. Because of this it is hardly a book for the beginner.

The book contains a great deal of information and will undoubtedly be useful to those engaged on electrophysiological work. It would, however, have been a better, but bigger, book if a more detailed treatment had been adopted. W. T. C.

ABSTRACTS and REFERENCES

Compiled by the Radio Research Board and published by arrangement with the Department of Scientific and Industrial Research

The abstracts are classified in accordance with the Universal Decimal Classification. They are arranged within broad subject sections in the order of the U.D.C. numbers, except that notices of book reviews are placed at the ends of the sections. U.D.C. numbers marked with a dagger (†) must be regarded as provisional. The abbreviations of the titles of journals are taken from the World List of Scientific Periodicals. Titles that do not appear in this List are abbreviated in a style conforming to it.

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ACOUSTICS AND AUDIO FREQUENCIES

534.232 : 534.321.9 **795**

An Ultrasonic Projector Design for a Wide Range of Research Applications.—E. J. Fry. (*Rev. sci. Instrum.*, Nov. 1950, Vol. 21, No. 11, pp. 940–941.) Description of equipment providing simple means of changing from one thickness-mode crystal to another of different frequency.

534.321.9 : 534.231 **796**

The Determination of Ultrasonic Fields in Fluids.—R. Krause. (*Z. angew. Phys.*, 15th Sept. 1950, Vol. 2, No. 9, pp. 370–373.) Axial and transverse field patterns were investigated for a quartz radiator of diameter 3 cm using a quartz detector of diameter 3 mm. The radiator operated at 1 Mc/s, emitting pulses of duration $1{\cdot}6\times10^{-5}$ to 3×10^{-4} sec. Measurements of the field along the axis are in good general agreement with calculated values based on Rayleigh's velocity-potential integral if due account is taken in the calculation of the damping effect of the radiator support. Discrepancies in the immediate neighbourhood of the radiator are due to the finite transverse dimensions of the detector. The importance of the interference field is demonstrated; it may give rise to local vibration pressures several times as great as would be expected from simple consideration of total power radiated.

534.321.9 : 534.511.1 **797**

Satellite Resonances in Ultrasonic Interferometry.—J. F. W. Bell. (*Proc. phys. Soc.*, 1st Nov. 1950, Vol. 63, No. 371B, pp. 958–964.) Satellite resonances of the gas in the tube of an ultrasonic interferometer are identified as mode resonances and are of the type described by Rayleigh. The presence of unresolved satellites in the principal interferometer resonance introduces a considerable error into absorption measurements. Results obtained by van Itterbeek and his co-workers (4186 of 1937) are shown to be in agreement with the Krasnushkin interferometer theory (2914 of 1944), which takes account of the effect of the multiple nature of the principal resonance. A criterion for the choice of crystals for ultrasonic absorption measurements is given.

534.321.9 : 534.613 **798**

A Method for the Measurement of the Sound Radiation Pressure in Ultrasonic Waves.—H. Goetz. (*Z. Naturf.*, Nov. 1949, Vol. 4a, No. 8, pp. 587–588.) The pressure is estimated from the observed deflection of small air bubbles ascending in a trough of paraffin in which a 4·2-Mc/s quartz generator transmits horizontally.

534.6 **799**

Note on the Definition of Complex Noise with Continuous Spectrum.—P. Chavasse & R. Lehmann. (*Ann. Télécommun.*, Nov. 1950, Vol. 5, No. 11, pp. 375–377.) Reasons are given for preferring a 'white' noise to a pure or wobbled tone as a source for acoustic measurements. The spectral curves obtained with such a source will differ according as the analysis is performed with a device in which $\Delta f/f$ is constant or one in which Δf is constant; hence it is important that the type of analyser used should be clearly indicated.

534.84 **800**

Vibrations of Enclosed Spaces with Deformable Elastic Boundaries.—T. Vogel. (*Ann. Télécommun.*, Nov. 1950, Vol. 5, No. 11, pp. 378–380.)

534.846 **801**

Relation between Architectural and Microphone Acoustics.—J. Bernhart. (*Ann. Télécommun.*, Oct. 1950, Vol. 5, No. 10, pp. 338–346.) The concept of reverberation time is by itself insufficient to define the acoustic characteristics of a studio when a microphone is used for sound pickup. Apparent reverberation is greater and variations in tonal quality are sharper. Parameters which may be considered in this case are discussed, especially acoustic perspective, the notion of 'sound planes', and the sound-source/microphone couple. Quality of reverberation varies according to the disposition of this couple. The influence of room contours and distribution of absorbing and reflecting surfaces on apparent reverberation are studied for certain experimental studios.

534.846 **802**

Acoustics of London's New Concert Hall.—(*Audio Engng*, Nov. 1950, Vol. 34, No. 11, pp. 26–64.) A brief discussion of the architectural plan of the South Bank Concert Hall. Variations from usual practice have been introduced in the arrangement of the orchestra to obtain acoustic improvements.

534.846 **803**

New Acoustic Theories.—J. Moir. (*FM-TV*, Nov. 1950, Vol. 10, No. 11, pp. 29–30.) Experiments carried out in England indicate that the sound-decay pattern of a studio or hall is more important than the reverberation as a criterion of acoustic quality. Equipment is described with which a complete picture of the decay curve of the reverberant sound resulting from an initial tone-pulse can be obtained, and typical curves are shown for auditoria with good and with poor acoustic quality. The particular features of various concert halls which contribute to their good acoustic properties are discussed.

534.85/.86 : [621.396.645.029.3+621.395.623.7 **804**

The FAS Audio System: Part 2.—M. B. Sleeper. (*FM-TV*, Nov. 1950, Vol. 10, No. 11, pp. 31–34.) Details are given of the arrangement of the three loudspeakers used, and of the 3-way crossover network operating at 350 c/s and 1 200 c/s, for which complete construction data are included. Best results are said to be obtained with the loudspeakers 5 to 10 ft apart. The bass loudspeaker is mounted near one end in the back wall of what is termed an air-coupler; this consists of a wooden box of dimensions about 6 ft × 16 in. × 6 in. (not critical), the walls being about 1 in. thick; an enclosed space between two floor joists will serve quite well. The resultant reproduction of the very-low-frequency notes of an orchestra, or the pedal notes of an organ, is surprisingly good. Part 1: 805 below.

534.85/.86 : 621.396.645.029.3 **805**

The FAS Audio System: Part 1.—M. B. Sleeper. (*FM-TV*, Oct. 1950, Vol. 10, No. 10, pp. 22–24..37.) Description of an amplifier and loudspeaker system designed to deliver sound-power output in about the same ratios as the outputs of the instruments used in broadcasting or in making a record. The relation between bass and treble is maintained at any level from full volume to bare audibility. The letters FAS stand both for the Fowler-Allison-Sleeper designs and for the Flewelling Audio System from which the designs here described were developed. Only three stages are used in the amplifier, with feedback from the secondary of the push-pull output transformer via a 30-kΩ resistor to the cathode of the first valve. Response is essentially flat from 20 c/s to 20 kc/s, and this flat characteristic is maintained by the output transformer at any level up to its full power rating. Circuit details are given both for the amplifier and its associated power-supply unit, which includes a double-Π filter to ensure a low hum level. The input stage has ample gain for a crystal pickup or a radio tuner, but the gain is insufficient for a reluctance pickup, which would require its own preamplifier. Part 2: 804 above.

534.85 **806**

Thorn Gramophone Needles.—A. M. Pollock. (*Wireless World*, Dec. 1950, Vol. 56, No. 12, pp. 450–452.) Illustrations are given showing the wear of thorn points after use for different playing times. An extensive series of tests indicates that thorn needles under light loading (needle pressure about 14 gm) give very good reproduction and that the resulting record wear is negligible.

534.852 : 621.395.625.3 **807**

A Magnetic Record-Reproduce Head.—M. Rettinger. (*J. Soc. Mot. Pict. Televis. Engrs*, Oct. 1950, Vol. 55, No. 4, pp. 377–390.) General principles of construction of a ring-shaped head, Type MI-10794, are discussed. Features of this head are: frequency range 30 c/s–18 kc/s, high sensitivity, absence of microphonics, low bias-current requirements, and low hum level, due to its small size.

621.395.61.001.11 **808**

Electromechanical Couplings.—F. A. Fischer. (*Frequenz*, Oct. 1950, Vol. 4, No. 10, pp. 262–267.) Laws governing the coupling of electrical and mechanical oscillatory systems are formulated, making use of the author's work on electromechanical transducers (552 of March and back reference).

621.395.623.7 **809**

Loudspeaker Cabinet Design.—D. E. L. Shorter. (*Wireless World*, Nov. & Dec. 1950, Vol. 56, Nos. 11 & 12, pp. 382–385 & 436–438.) The acoustical and electrical damping of loudspeakers fitted in closed cabinets is discussed, and experimental results obtained in the course of development work on loudspeaker cabinets during 1938–1947 are presented. Although the 'infinite-baffle' type of cabinet of ample volume is often regarded as the ideal mounting, the full potentialities of such a system cannot always be realized in practice. The general characteristics of vented cabinets are described and details are given of the cabinet adopted for a 15-in. coaxial loudspeaker for B.B.C. monitoring purposes. Performance data obtained with this combination indicate that a vented cabinet is capable of doing justice to the best loudspeaker units at present available.

621.395.625.3 **810**

Accidental Printing in Magnetic Recording.—E. D. Daniel & P. E. Axon. (*B.B.C. Quart.*, Winter 1950/1951, Vol. 5, No. 4, pp. 241–256.) The weak fields produced by portions of a magnetic tape influence adjacent portions, so that spurious signals may occur in reproduction. The extent of the effect and its dependence on various parameters are investigated theoretically and experimentally, together with methods of reducing the ratio of unwanted to wanted signals. The level of accidental printing depends on the original recorded intensity and wavelength, and on the separation between adjacent layers of film. Storage temperature should be low. The time-decrease of spurious signal is important, and h.f. partial erasure on replay may be useful.

621.395.625.3 **811**

Magnetic Recording of Sound.—F. Gallet. (*Onde élect.*, Nov. 1950, Vol. 30, No. 284, pp. 449–457.) General survey of present-day practice and equipment, and discussion of problems encountered, mainly with reference to magnetic-tape high-fidelity apparatus for broadcasting; other methods and equipment are mentioned briefly.

AERIALS AND TRANSMISSION LINES

621.392.09 **812**

Surface Waves and their Application to Transmission Lines.—G. Goubau. (*J. appl. Phys.*, Nov. 1950, Vol. 21, No. 11, pp. 1119–1128.) Two types of non-radiating surface wave on a wire are discussed theoretically. The first (discussed by Sommerfeld in 1899) is guided by a wire of finite conductivity; it exhibits an attenuation much less than that of a wave in a conventional guide or coaxial cable but the spatial extension of its field is very large. This type of guided wave would only be practically useful at frequencies above 3 000 Mc/s.

The second type of wave is guided by a conductor whose surface is coated with a dielectric or threaded in order to reduce the phase velocity. Although this guide has greater losses than the Sommerfeld wire, its field is much more confined, and it becomes practicable above 100 Mc/s. Waves may be launched on the conductor from a coaxial cable by a horn. Experiment shows agreement with the theoretical losses. See also 281 of February.

621.392.26† : 621.3.09 **813**

The Stability and Attenuation of Guided Electric and Magnetic Waves of the Same Critical Frequency.—R. Müller. (*Z. Naturf.*, June 1949, Vol. 4a, No. 3, pp.

218–224.) The calculation of waves in an infinitely long perfectly conducting guide is reduced to a two-dimensional boundary-value problem whose many solutions include the electric (E) and magnetic (H) modes. E and H modes with the same critical frequency correspond to a multiple eigenvalue. Attenuation due to finite conductivity is treated as a perturbation, whose calculation also enables the case of degeneracy to be considered consistently. In general, the degenerate eigenvalue corresponds to linear combinations of E and H modes, these combinations representing the stable modes to which an attenuation constant can be assigned in an actual waveguide. Important examples of degenerate modes are discussed: the E_{1n} and H_{0n} modes in circular-section guides remain stable when attenuation is taken into account, whereas the E_{1m} and H_{1m} modes in rectangular guides become unstable except when the rectangle becomes a square.

621.392.26† : 621.392.5.001.11 **814**

The Application of Quadripole Theory to Waveguide Systems.—F. W. Gundlach. (*Arch. elekt. Übertragung*, Sept. 1950, Vol. 4, No. 9, pp. 342–348.) Quadripole theory can be applied to waveguide systems without regard to particular values of current, voltage or characteristic impedance. The discussion considers only the concepts of field impedance (ratio of transverse electric field to transverse magnetic field), phase difference between input and output planes, and efficiency. Simple relations are derived, capable of representation by circle diagrams.

621.392.26† : 621.396.67 **815**

Slotted Waveguides and their Applications as Aerials: Experimental Study.—J. Ortusi & G. Boissinot. (*Ann. Radioélect.*, Oct. 1950, Vol. 5, No. 22, pp. 308–320.) Results are reported of measurements made on guides with single and multiple slots to verify the theory presented previously (2129 of 1950). The modification of the reflection factor for a single slot observed in the case of an array is assumed to be due to waves circulating between adjacent slots. This concept is more complex than the classical one of impedance in an equivalent line, but simplifies physical interpretation of the propagation phenomena and prediction of performance within the pass band. Requirements are discussed for a slotted guide to give a specified performance as an aerial. To obtain a wide pass band, a structure combining several guides is necessary. Compared with the paraboloid-sector aerial, the waveguide structures are smaller and easier to rotate.

621.392.26† : 621.396.67 **816**

Radiation of a Dipole inside a Waveguide of Rectangular Cross-Section.—T. Vellat. (*Bull. schweiz. elektrotech. Ver.*, 29th Oct. 1939, Vol. 40, No. 22, pp. 860–869. In German.) The radiation can be calculated by applying the principle of electrical reflection and using integrals of Hankel functions. The waves radiated are plane although the source is cylindrical. The influence of the radiating body extends uniformly over the whole section. This is of great practical importance, because dipole devices, which are mechanically simple, can therefore be used for emitting, collecting and controlling the radiation. Dielectric pins are used for matching to aerials, detectors, etc.

621.392.5 **817**

Radiation Resistance of Skew-Wire Radio-Frequency Transmission Lines.—S. S. Banerjee & R. R. Mehrotra. (*Indian J. Phys.*, Sept. 1949, Vol. 23, No. 9, pp. 403–409.) A general formula, applicable for any orientation of the lines with respect to each other, is derived and applied to six special cases of practical interest. Results for one of these cases were confirmed experimentally.

621.396.67 **818**

Ice Formation on Aerials.—F. D. Bolt. (*B.B.C. Quart.*, Winter 1950/1951, Vol. 5, No. 4, pp. 236–240.) The method of formation, effect, and removal of frost and 'glaze ice' are discussed. With s.w. aerial arrays the added weight of glaze ice may be many times the weight of the aerials themselves, so that serious damage may be caused unless the aerials were originally designed to withstand heavy loading. In the case of television aerials the change of aerial impedance due to a coating of ice may result in the formation of ghost images on receiver screens, owing to mismatch between the transmitting aerial and its feeder. To prevent ice formation on the folded dipoles of the Sutton Coldfield transmitter, heater elements providing 7·5 kW for each dipole are switched on when the temperature at the top of the aerial mast falls to 3° C.

621.396.67 **819**

The Theory of Receiving Aerials.—J. Grosskopf. (*Frequenz*, Oct. 1950, Vol. 4, No. 10, pp. 249–261.) The limits of applicability of transmission-line theory to nonrectilinear aerial arrangements are discussed, and a theory is developed for circular and rhombic receiving aerials with nonstationary current distribution. Even for frame aerials of small size, slight departures from previously accepted theory manifest themselves as a dipole effect. Other common nonrectilinear arrangements, in particular asymmetrical ones, are also considered.

621.396.67 **820**

Diffraction by Paraboloids of Revolution.—J. Ortusi & J. C. Simon. (*Ann. Radioélect.*, Oct. 1950, Vol. 5, No. 22, pp. 321–330.) Analogies between the properties of cm and light waves are discussed, and the Huyghens-Kottler formulae are applied to the determination of the field near the focus of a paraboloid of revolution. Results of measurements made at a wavelength of 8 cm with three different paraboloids, using a crystal detector, are in good agreement with the theory and indicate that, using the field of the geometrically reflected wave as source, the Huyghens-Kottler formulae are valid for exact calculations even when the dimensions of the diffracting element are of the order of 10λ. Axial gain and the possibilities of controlling beam direction by displacing the source are investigated.

621.396.67 **821**

Theory of Axially Slitted Circular and Elliptic Cylinder Antennas.—D. R. Rhodes. (*J. appl. Phys.*, Nov. 1950, Vol. 21, No. 11, pp. 1181–1188.) Application of Sommerfeld's method to the diffraction of a plane wave with arbitrary angle of incidence and polarization by perfectly conducting cylinders of infinite length having a slot parallel to the axis. The case of a slot of infinitesimal width (or slit) is considered in detail and the operation of a slitted cylinder as a travelling-wave system is analysed. Radiation patterns for a cylinder with a single slit and with two diametrically opposite slits are given.

621.396.67 **822**

Approximate Method of Deriving the Standing Wave Ratio Produced by an Aerial Array.—T. C. Cheston. (*Marconi Rev.*, 4th Quarter 1950, Vol. 13, No. 99, pp. 168–174.) The array is one in which a large number of radiating elements are distributed along a feeder, and the method is based on an analysis of the vector diagram of the reflections, along the feeder, from successive elements. The errors introduced by the assumption that the array is infinitely long are assessed.

621.396.67 **823**

New Communications Antenna.—M. W. Scheldorf. (*FM-TV*, Sept. 1950, Vol. 10, No. 9, pp. 14–15.) The

Andrew Type-3000 aerials for communication in the ranges 148–162 Mc/s and 162–174 Mc/s are designed to provide a circular horizontal pattern, high gain, low number of feed points, low wind loading, and negligible coupling to the mast. An array of eight folded dipoles is used; the feed harness and method of stacking are described in detail. Performance measurements are shown in diagrams.

621.396.677 **824**

Microwave Antennas.—J. Racker. (*Radio & Televis. News, Radio-Electronic Engng*, Oct. 1950, Vol. 15, No. 4, pp. 15A–17A, 31A.) Directivity and gain of parabolic, horn and lens aerials are among the factors discussed. Suitable methods of excitation and types of transmission-line feeder are also briefly considered.

621.396.679.4 **825**

Aerial Feeder Connections.—W. T. Cocking. (*Wireless World*, Dec. 1950, Vol. 56, No. 12, pp. 426–428.) Practical consideration of the coupling of a dipole to an unbalanced receiver circuit by either a balanced line or a coaxial cable. The efficiency of various systems in providing signal transfer, impedance match, balance and rejection of interference is discussed. Particular attention is devoted to a 'balun' circuit which embodies two inductors and two capacitors and avoids the need for a screened transformer.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.012.3 **826**

Use of Conductance, or G, Curves for Pentode-Circuit Design.—K. A. Pullen. (*Tele-Tech*, Nov. 1950, Vol. 9, No. 11, pp. 38–40, 45.) Sets of curves applicable to Type 7E7 valves are shown and their use in circuit design is explained. See also 292 of 1950.

621.314.2 **827**

Developments in Small Chokes and Power Transformers.—(*Electronic Engng*, Nov. 1950, Vol. 22, No. 273, pp. 450–453.) Transformers used in Naval Service from 1936 to 1949 are described briefly, and the latest design in detail. This transformer is oil-filled, its terminal seals are made of fused aluminium oxide, and its case is deep drawn in two parts. C-type cores are used; these have several advantages over orthodox silicon-iron stampings. This type of transformer is the only one to qualify fully as an inter-Service standard type.

621.314.22.015.7 **828**

A Method for Designing Pulse Transformers.—H. S. Kirschbaum & C. E. Warren. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part II, pp. 971–978.) Description of a method that takes account of transformer terminating impedances and permits control of certain features of the output waveform. The design relations give a clear indication of the possibility of realizing a design for a given set of specifications and, in many cases, provide several alternative designs to meet special requirements.

621.314.3† **829**

The Dynamoelectric Amplifier: Class-A Operation.—R. M. Saunders. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part II, pp. 1368–1373.) Various dynamoelectric amplifiers are compared with the electronic amplifier, and the static and dynamic characteristics of both the single- and 2-stage dynamoelectric amplifiers are discussed from the a.c. steady-state point of view. The dynamic characteristics are calculated from equivalent circuits and compared with test results in the form of frequency-response and phase-angle curves. Negative-feedback circuits and response curves are also presented and the effects of feedback are noted. See also 46 of January.

621.314.3† **830**

Self-Saturation in Magnetic Amplifiers.—W. J. Dornhoefer. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part II, pp. 835–846. Discussion, pp. 846–850.) Full paper. Summary abstracted in 565 of 1950.

621.316.8 : 621.396.822 : 621.317.7 **831**

The Measurement of Noise in Resistors.—Oakes. (See 945.)

621.319.4 **832**

Power Capacitors with Ceramic Dielectric.—J. Peyssou. (*Ann. Radioélect.*, Oct. 1950, Vol. 5, No. 22, pp. 391–406.) The influence of the pottery industry is seen in the general adoption of dish and pot shapes for ceramic-dielectric capacitors. Design is discussed in relation to performance, viz., specified capacitance, operating voltage, maximum h.f. power and field strength. Heating during operation is studied, particularly heating due to the Joule effects in the electrodes; this can be reduced by the use of suitable types of connector. Brief descriptions are included of equipment and methods for the measurement of maximum reactive power and maximum h.f. field strength.

621.392.43 **833**

Transformation of an Arbitrary Complex Impedance to a Given Resistance by means of a H.F. Line Section.—P. Maurer. (*Arch. elekt. Übertragung*, Sept. 1950, Vol. 4, No. 9, pp. 349–352.) Coaxial-line sections are commonly used for matching a load to a generator in the dm-wave band, stubs being most often used. In many cases the problem can be simply solved by using a single coaxial-line section of appropriate length and characteristic impedance. Formulae for such sections are derived from basic equations of current and voltage distribution and are represented in polar diagrams. The sections are assumed lossless.

621.392.5 **834**

Circuit Analysis of Linear Varying-Parameter Networks.—L. A. Zadeh. (*J. appl. Phys.*, Nov. 1950, Vol. 21, No. 11, pp. 1171–1177.) Theory is presented which is essentially a generalization of the familiar frequency-domain theory of fixed linear networks. Such basic concepts as impedance, admittance, gain, etc., are extended to linear varying-parameter networks and their important properties are outlined. Extensions are given also of the general mesh and node equations, Thévenin's theorem, dualization, and some other relations that hold in the case of fixed networks. Many theorems, properties, and relations that hold in the case of fixed networks may be extended with proper modifications to linear varying-parameter networks.

621.392.5 : 621.315.212 **835**

Attenuation and Delay Equalizers for Coaxial Lines.—W. R. Lundry. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part II, pp. 1174–1179.) Full paper. Summary abstracted in 1619 of 1950.

621.392.5 : 621.315.212 : 621.397.743 **836**

Equalization of Coaxial Lines.—K. E. Gould. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part II, pp. 1187–1192.) Full paper. Summary abstracted in 2152 of 1950.

621.392.6 **837**

Generalized Network Theory.—U. Kirschner. (*Arch. elekt. Übertragung*, Sept. 1950, Vol. 4, No. 9, pp. 367–373.) By means of the 'oriented path complex', the circuit equations are derived for a generalized network with r degrees of freedom, i.e., with r independent circuits. The equations are solved by means of Cramer's rule, leading to a determination first of the iterative matrix of

a $2r$-pole, and finally, by splitting off and eliminating $(r-k)$ columns and rows, of the iterative matrix of a $2k$-pole $(k<r)$.

621.395.669.3 **838**

A Simple Crackle Eliminator using Selenium Rectifiers as Amplitude Limiters.—K. H. Werner. (*Arch. elekt. Übertragung*, Sept. 1950, Vol. 4, No. 9, pp. 374–376.) In the characteristic of the Se rectifier the transition from the high-resistance to the low-resistance condition is so located that the rectifier requires no bias when used in a low-voltage limiter. Overload protection is also unnecessary. Extremely simple limiter circuits are thus possible, comprising merely capacitors and rectifiers. Rectifiers of different sizes were investigated; measurements are reported and discussed.

621.396.6 **839**

The Design of Electronic Equipment using Subminiature Components.—M. L. Miller. (*Proc. Instn Radio Engrs, Aust.*, Nov. 1950, Vol. 11, No. 11, pp. 284–289.) Reprint. See 1372 of 1950.

621.396.6 **840**

Proceedings, Symposium on Improved Quality Electronic Components.—(*Tech. Bull. nat. Bur. Stand.*, Oct. 1950, Vol. 34, No. 10, p. 151.) Fifty-two papers were presented at this conference, held in May 1950, and sponsored by the American Institute of Electrical Engineers, the Institute of Radio Engineers and the Radio Manufacturers' Association, with co-operation of U.S. Government departments. Copies of the Proceedings are available from the Trielectro Company, 1 Thomas Circle, Washington 5, D.C., at $3.50.

621.396.611.4 : 621.317.352 **841**

Simple Method for Measurement of Variations of Damping of Centimetre Waves.—E. M. Philipp. (*Acta phys. austriaca*, Feb. 1949, Vol. 2, Nos. 3/4, pp. 239–244.) Description of a method applicable to cavity resonators. The quasistationary-oscillatory-circuit method commonly used for measurement of voltage resonance is adapted to the u.s.w. range. The limits of validity of the method are discussed.

621.396.615 **842**

The Generation of Oscillations in a Phase-Shift Oscillator.—W. Taeger. (*Funk u. Ton*, Oct. 1950, Vol. 4, No. 10, pp. 525–530.) Mathematical analysis of the oscillatory condition in a circuit with an even number of identical stages and a Wien-bridge feedback link. See also 597 of March.

621.396.615.015.7† **843**

Pulse Generator of Fixed Repetition Rate.—F. A. Benson & R. M. Pearson. (*Wireless Engr*, Dec. 1950, Vol. 27, No. 327, pp. 285–288.) A very simple circuit for producing short pulses from an a.c. source (about 200 V r.m.s.) is described and its operation analysed. Negative pulses with an amplitude of about 60 V and a rise time $<1\ \mu$s are obtained. The pulse repetition rate is identical with the frequency of the a.c. source.

621.396.615.14 **844**

Short-Wave Self-Oscillator Circuits.—E. Green. (*Marconi Rev.*, 4th Quarter 1950, Vol. 13, No. 99, pp. 135–152.) The circuits considered are those based on pairs of triodes with the cathodes, anodes or grids connected, and the single-valve equivalents with one electrode earthed. It is shown how the values of the external circuit components combine with the interelectrode capacitances to produce conditions for oscillation, and how losses in the grid circuit can be compensated.

621.396.645 **845**

The Grounded-Grid Amplifier.—J. Roorda. (*Electronic Engng*, Nov. 1950, Vol. 22, No. 273, pp. 478–480.) A mathematical analysis of the essential characteristics of the grounded-grid triode used as a h.f. linear amplifier, interelectrode capacitances being taken into account. Conditions for resonance and stability are discussed. Formulae are deduced for input admittance and voltage amplification.

621.396.645 **846**

Cathode-Follower Performance.—A. J. Shimmins. (*Wireless Engr*, Dec. 1950, Vol. 27, No. 327, pp. 289–293.) A mathematical analysis of the response of cathode-follower circuits to pulse and sawtooth signals. The distortion in practical circuits may be readily calculated.

621.396.645.015.7† **847**

Pulse Amplifier for Fast Ionization Chambers and Proportional Counters.—(*Electronic Engng*, Nov. 1950, Vol. 22, No. 273, p. 469.) A.E.R.E. Specification 120 describes a 2-unit pulse amplifier, Type 1049B, particularly suitable for coincidence work and counting in the presence of a high background-level. Full details can be obtained on request from the Atomic Energy Research Establishment, Harwell, Berkshire.

621.396.645.35 **848**

D.C. Amplifier for Biological Application.—P. O. Bishop & E. J. Harris. (*Rev. sci. Instrum.*, Nov. 1950, Vol. 21, No. 11, p. 904.) Corrections to article abstracted in 2174 of 1950.

621.396.645.35 **849**

Wide-Band D.C. Amplifier Stabilized for Gain and for Zero.—A. J. Williams, Jr, W. G. Amey & W. McAdam. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part II, pp. 811–815. Discussion, p. 815.) Full paper. Summary abstracted in 598 of 1950.

621.396.643.572 **850**

Positive Feedback in A.F. Amplifiers.—C. H. Banthorpe. (*Electronic Engng*, Nov. 1950, Vol. 22, No. 273, p. 473.) Positive feedback can be used to compensate for loss of gain due to negative feedback. An application of this principle in the a.f. stages of a broadcasting receiver is described.

621.319.4 **851**

Bauelemente der Nachrichtentechnik. Teil 1: Kondensatoren. [Book Review]—H. Nottebrock. Publishers: Schiele & Schön, Berlin, 1949, 172 pp., 9 DM. (*Bull. schweiz. elektrotech. Ver.*, 29th Oct. 1949, Vol. 40, No. 22, p. 880. In French.) Gives practical information useful in selecting capacitors for telecommunications applications. The manufacture and properties of the various types, grouped according to dielectric, are described. Tests and test gear and performance in various circuits are discussed briefly.

GENERAL PHYSICS

537.523.4 **852**

Voltage Gradients in High-Current Spark Channels.—J. E. Allen. (*Research, Lond.*, Nov. 1950, Vol. 3, No. 11, pp. 527–528.) Using an impulse generator producing peak currents up to 500 kA, oscillographic measurements of voltage drop across short spark-channels were observed for several gap widths. In the range 188–265 kA, voltage gradients were high and increased with current. The effect on the discharge of metal vapour from the electrodes was appreciable.

537.525 : 538.56 **853**

Free Spherical Electromagnetic Oscillations in Spaces containing Plasma.—W. O. Schumann. (*Z. Naturf.*,

Oct. 1949, Vol. 4a, No. 7, pp. 486–491.) Mathematical analysis is given for the following cases: a conducting plasma-filled sphere; a dielectric and a conducting sphere immersed in plasma; a plasma sphere in air. The effect of the frequency-dependence of the dielectric constant on the oscillation processes is discussed, and in particular the possibility of new modes of oscillation resulting from negative values of dielectric constant.

537.533.7 : 621.385.029.63/.64 **854**

Dynamic Electron Flow under the Influence of Dynamic Fields.—H. W. König. (*Acta phys. austriaca*, Feb. 1949, Vol. 2, Nos. 3/4, pp. 312–334.) A plane electron flow is subjected to an electrical control field arranged in n sections, the control current in each section having the same amplitude. The phases are so chosen that the current in any section lags behind that in the previous section by an amount corresponding to the time taken by the electrons to traverse the section. In the limiting case a dynamic control field is obtained which moves at each point with the velocity of the electrons. In this case the field and velocity distributions are given by the same equations as for quasistationary flow, when account is taken of the phase lag in the periodic terms due to the finite value of the transit angle. The alternating field strength produced in the electron stream by the action of the control field increases in the case of the quasistationary field as the first power of the transit angle, but, on the other hand, as the square of the angle in the case of the dynamic field. In consequence, for equal transit angles, a considerably greater amplification can be obtained with dynamic control of the electron velocity. Since the noise characteristics are about the same in both cases, the limiting sensitivity is appreciably improved. Diagrams are given showing the field and velocity distributions for the case in which the electrons in the control path move with constant velocity. Application of the theory to the travelling-wave valve is outlined.

538.221 **855**

Studies of the Propagation Velocity of a Ferromagnetic Domain Boundary.—H. J. Williams, W. Shockley & C. Kittel. (*Phys. Rev.*, 15th Dec. 1950, Vol. 80, No. 6, pp. 1090–1094.) Experimental results are given for the velocity of propagation of a single domain boundary in a crystal of silicon-iron with a simple domain structure. The results are discussed with reference to the eddy-current anomaly for ferromagnetic materials.

538.311 **856**

The Magnetic Field of a Plane Circular Loop.—C. L. Bartberger. (*J. appl. Phys.*, Nov. 1950, Vol. 21, No. 11, pp. 1108–1114.) "The axial and radial components of the magnetic field of a plane circular loop are expressed in terms of cylindrical coordinates. The expressions involve two integrals which are related to certain of the complete elliptic integrals. Tables of values of these integrals are presented. Interpolation in these tables facilitates rapid calculation of the field components."

538.566.2 **857**

Research on the Propagation of Sinusoidal Electromagnetic Waves in Stratified Media: Application to Thin Layers: Part 1.—F. Abelès. (*Ann. Phys., Paris*, Sept./Oct. 1950, Vol. 5, pp. 596–640.) This paper deals with stratified systems in general; the second part is to deal with homogeneous thin layers. The essence of the method is, starting from Maxwell's equations, to represent stratified media having any values of dielectric constant and magnetic permeability by matrices with two rows and two columns. This facilitates consideration of discontinuous stratification. A method is developed for integrating differential field equations without restriction on the laws of variation of the characteristic parameters of the medium. General expressions are given for the coefficients of reflection and transmission and the corresponding phase shifts suffered by the field vectors, two cases of particular practical importance being treated in detail. The first is that where the thickness of the medium is small in relation to the wavelength of the incident waves. The second corresponds to a medium of any thickness where the variations of the parameters are very slow, as for example with a slightly inhomogenous thin layer. Some general theorems on stratified media are proved, and the development of the general theory from that for an infinite stack of infinitely thin homogeneous layers is indicated. Analogies with other problems of physics and mechanics are discussed. A convenient method is described for studying media whose parameters are periodic in space.

538.566.2 **858**

Artificial Field Equations for a Region where μ and ϵ Vary with Position.—P. D. P. Smith. (*J. appl. Phys.*, Nov. 1950, Vol. 21, No. 11, pp. 1140–1149.) Mathematical treatment of waves in a continuously variable medium is given which is similar to that used by Weyl for the relativistic effect of gravitational potential. The TE and TM cases are considered and also the fields derived from a 4-potential. Application of the method in cylindrical coordinates is used to derive formulae for the TE, TM and TEM waves. Solutions are derived for specific distributions of μ and ϵ, with applications to curved guides, horns and coaxial lines.

538 **859**

Electromagnetic Fields: Theory and Applications. Vol. 1—Mapping of Fields. [Book Review]—E. Weber. Publishers: J. Wiley & Sons, New York, 1950, 590 pp., $10.00. (*J. Franklin Inst.*, Dec. 1950, Vol. 250, No. 6, pp. 586–587.) A comprehensive survey, with many examples illustrating the basic principles; it presents clearly the relations between analytical, experimental, graphical and numerical methods of solving static-field problems. Recommended as a textbook for a degree course and as a reference work.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.72 : 621.396.822 **860**

The Polarization of Thermal 'Solar Noise' and a Determination of the Sun's General Magnetic Field.—S. F. Smerd. (*Aust. J. sci. Res., Ser. A*, June 1950, Vol. 3, No. 2, pp. 265–273.) "The equation of transfer of radiation and the magneto-ionic theory are used to derive expressions for the degree of polarization of thermal 'solar noise' due to a general magnetic field of the sun. In particular, the net polarization of 600-Mc/s radiation corresponding to the maximum phase of the eclipse of 1st November, 1948, as seen from Melbourne, Victoria, is evaluated theoretically and compared with observational evidence. This leads to an upper limit of 11 gauss for the surface field-strength at the solar poles at the time of observation."

523.72 : 621.396.822 **861**

Solar Radiation at 1200 Mc/s, 600 Mc/s, and 200 Mc/s.—F. J. Lehany & D. E. Yabsley. (*Aust. J. sci. Res., Ser. A*, June 1950, Vol. 3, No. 2, p. 350.) Correction to paper abstracted in 616 of 1950.

523.745 **862**

The Physical Meaning of the Character Figures of Solar Phenomena.—G. Righini & G. Godoli. (*J. geophys. Res.*, Dec. 1950, Vol. 55, No. 4, pp. 415–422.) Character figures and areas of Ca-flocculi, bright and dark H_α-flocculi are compared for the period 1932–1949. The character figures appear to be a function of the areas only.

523.746 **863**

Current Interpretation of the Sunspot Phenomenon.—W. Grotrian. (*Z. angew. Phys.*, 15th Sept. 1950, Vol. 2, No. 9, pp. 376–390.) A comprehensive survey; text of a lecture delivered at Munich in March 1950. Observations of fluctuations of both solar magnetic field and solar diameter are consistent with the 11-year period of the sunspot cycle, but further systematic observations over at least 22 years are needed to check the various theories.

523.746 "1950.07/.09" **864**

Provisional Sunspot-Numbers for July to September, 1950.—M. Waldmeier. (*J. geophys. Res.*, Dec. 1950, Vol. 55, No. 4, p. 488.)

523.854 : 621.396.822 **865**

Galactic Radiation at Radio Frequencies: Part 2—The Discrete Sources.—G. J. Stanley & O. B. Slee. (*Aust. J. sci. Res., Ser. A*, June 1950, Vol. 3, No. 2, pp. 234–250.) A description is given of the special techniques necessary in the observation of the very small differences in noise intensity between the discrete sources and the background continuum. The results of measurements of the position and angular width of the discrete sources are discussed, and the present known data are tabulated. Measurements of intensity within the band 40–160 Mc/s showed that for three sources intensity changed more rapidly with frequency than did the background noise, while for a fourth source it changed less rapidly. The short-period fluctuations in intensity of the source in Cygnus are discussed; evidence is presented which suggests that their origin is in the ionosphere rather than outside it. Part 1: 348 of February (Bolton & Westfold). Part 3: 866 below.

523.854 : 621.396.822 **866**

Galactic Radiation at Radio Frequencies: Part 3—Galactic Structure.—J. G. Bolton & K. C. Westfold. (*Aust. J. sci. Res., Ser. A*, June 1950, Vol. 3, No. 2, pp. 251–264.) From r.f. observations it is deduced that the sun is situated in or near an arm of a spiral galaxy. The r.f. data are analysed and optical evidence in favour of the spiral form is presented. The sense of rotation of the galaxy—that of the spiral unwinding—is in accordance with the theories of Lindblad and Milne. Part 2: 865 above.

523.854 : 621.396.822 **867**

Survey of Galactic Radio-Noise at 200 Mc/s.—C. W. Allen & C. S. Gum. (*Aust. J. sci. Res., Ser. A*, June 1950, Vol. 3, No. 2, pp. 224–233.) Using a Yagi aerial array of known sensitivity pattern, galactic radio-noise was measured at 200 Mc/s during a systematic scanning of the whole sky south of declination 45°N. The measurements of intensity are expressed relative to the level at the galactic poles and are accurate to within about 20% in most regions, with a probable error of 1° in location. After correction for the integration effect of the aerial pattern, contour plots of the distribution of the radiation were made. Galactic noise is suggested as a standard for measurements of solar noise.

532.517.4 : 551.510.5 : 621.396.11 **868**

Scattering of Electromagnetic Waves by Atmospheric Turbulence.—Megaw. (See 973.)

550.37 : 551.594.21 **869**

Thunderstorms and the Earth's General Electrification.—O. H. Gish & G. R. Wait. (*J. geophys. Res.*, Dec. 1950, Vol. 55, No. 4, pp. 473–484.) The conductivities and electric field strengths were measured above 21 thunderstorms. The conductivity was not altered appreciably by the presence of the storms. All storms showed a positive current flowing upwards, the total current ranging from 0 to 1·4 A, with an isolated reading of 6·5 A. The average value, omitting the latter high reading, was 0·5 A. In ten cases the electric-field profile corresponded with that of a simple bipolar model. The observations support Wilson's hypothesis concerning the effect of thunderstorms in maintaining the earth's permanent negative charge.

550.38 "1950.04/.06" **870**

International Data on Magnetic Disturbances, Second Quarter, 1950.—J. Bartels & J. Veldkamp. (*J. geophys. Res.*, Dec. 1950, Vol. 55, No. 4, pp. 485–487.)

550.38 "1950.07/.09" **871**

Cheltenham [Maryland] **Three-Hour-Range Indices *K* for July to September, 1950.**—R. R. Bodle. (*J. geophys. Res.*, Dec. 1950, Vol. 55, No. 4, p. 488.)

550.384 **872**

Results on Geomagnetic *K*-Indices for the International Polar Year 1932–33.—J. Bartels. (*J. geophys. Res.*, Dec. 1950, Vol. 55, No. 4, pp. 427–435.)

550.385 : 551.594.52 **873**

The Southward Shift of the Auroral Zone during Intense Magnetic Storms.—V. C. A. Ferraro. (*J. geophys. Res.*, Dec. 1950, Vol. 55, No. 4, p. 493.) Comment on a paper by Nagata (2501 of 1950). The southward movement of the auroral zone in the northern hemisphere during severe magnetic storms can be explained by the theory of Chapman & Ferraro as well as by Störmer's original auroral theory.

550.385 "1950.04/.09" **874**

Principal Magnetic Storms [April–Sept. 1950].—(*J. geophys. Res.*, Dec. 1950, Vol. 55, No. 4, pp. 489–492.)

551.510.52 : [551.543+551.524.7 **875**

Day-to-Day Variations of Pressure and Temperature in the Lower Troposphere to 5-km Height, and their Mutual Statistical Synoptical Relations.—H. Hoinkes. (*Arch. Met. Geophys. Bioklimatol.*, 28th March 1950, Vol. 2, Nos. 2/3, pp. 239–300. Bibliography, pp. 300–304.) Correlation of many thousands of observations at 70 stations in various parts of Europe, the North Atlantic, North Africa, Spitzbergen and Inner Asia.

551.510.53 : 001.4 **876**

Upper Atmospheric Nomenclature.—S. Chapman. (*J. geophys. Res.*, Dec. 1950, Vol. 55, No. 4, pp. 395–399; *J. atmos. terr. Phys.*, 1950, Vol. 1, No. 2, pp. 121–124.) Many new terms characterizing the various atmospheric regions and levels are suggested.

551.510.535+551.594.5 **877**

Corpuscular Influences upon the Upper Atmosphere.—S. Chapman. (*J. geophys. Res.*, Dec. 1950, Vol. 55, No. 4, pp. 361–372.) A critical review of the evidence for and against the corpuscular theory of magnetic storms and aurorae, including discussion of certain crucial tests and difficulties. The observed solar and terrestrial phenomena to be explained are examined in detail. It is concluded that the available data may be most readily interpreted in terms of the corpuscular theory. The most direct evidence for the theory is given by recent observations of the broadening of the hydrogen lines in the auroral spectrum.

551.510.535 **878**

The Lowest of the Ionized Layers of the Upper Atmosphere.—D. Stranz. (*Tellus*, Aug. 1950, Vol. 2, No. 3, pp. 150–157.) Discussion of the properties of the D layer and of various theories of its formation.

551.510.535 **879**

Thermal Splitting of Ionosphere Layers.—O. Burkard. (*Arch. Met. Geophys. Bioklimatol.*, 28th March 1950, Vol. 2, Nos. 2/3, pp. 308–314.) The rate of ion production is calculated as a function of height, assuming a stratified temperature distribution. Under certain conditions, such a distribution can give rise to two maxima of ionization. A similar process may account for the splitting of the ionosphere F layer during the day.

551.510.535 **880**

Prediction of Ionospheric Conditions for Antipodal Stations.—G. R. White & R. F. Potter. (*Trans. Amer. geophys. Union*, Oct. 1949, Vol. 30, No. 5, pp. 686–690.) For another account see 1660 of 1949.

551.510.535 **881**

Ionosphere over Calcutta.—S. S. Baral & A. P. Mitra. (*J. atmos. terr. Phys.*, 1950, Vol. 1, No. 2, pp. 95–105.) Records made at Calcutta during the solar half-cycle Jan. 1945–June 1950 were analysed in order to determine the following ionospheric parameters: rate of electron production, temperature, effective coefficient of recombination. The value of the earth's magnetic field at the average height of the F_2 region was also determined. Graphs show the variations of the various quantities.

551.510.535 **882**

Studies of the F_2 Layer in the Ionosphere: Part 1—The Position of the Ionospheric Equator in the F_2 Layer.—E. Appleton. (*J. atmos. terr. Phys.*, 1950, Vol. 1, No. 2, pp. 106–113.) "The seasonal variations of the noon equivalent heights of the F_2 layer at a number of stations are examined and the variations characteristic of the northern hemisphere and of the southern hemisphere identified. It is shown that the change-over from one type of variation to the other occurs in a region which is more nearly coincident with the magnetic equator than with the geographical equator."

551.510.535 **883**

27-Day Variations in F_2-Layer Critical Frequencies at Huancayo.—J. Bartels. (*J. atmos. terr. Phys.*, 1950, Vol. 1, No. 1, pp. 2–12.) "The solar radiation responsible for the production of F_2-layer ionization is already known to change with the 11-year sunspot cycle. The question has therefore been examined whether analogous changes occur in the course of the solar rotation of about 27 days period in cases where the sunspot numbers R show appreciable quasi-persistent periodicities. After correcting for lunar tidal influence, variations of the type in question have been found in the noon values of fF_2 for Huancayo, Peru, using the superposed epoch method. Such variations are found to be of the order of 6 to 10%. Changes in fF_2 accompanying changes in R appear to be delayed by about two days, but a scatter analysis by means of synchronized harmonic dials throws doubt on the statistical significance of such a lag. The lunar tides in the noon values of fF_2, examined for comparison, cause total semimensual changes of more than 10% in southern summer, but only 2 to 3% in southern winter. These seasonal changes in the lunar tidal effect $L(fF_2)$ are much larger than those disclosed in the quantitative effects of changes of R on fF_2. The use of these results in ionospheric forecasting is briefly discussed."

551.510.535 : 523.745 **884**

Comparison of Variously Derived Solar Indexes.—H. S. Moore & M. Stein. (*J. geophys. Res.*, Dec. 1950, Vol. 55, No. 4, pp. 423–425.) Values of the ionospheric solar-activity index S_I based on data from Washington, Huancayo and Watheroo show slightly closer correlations with the noon values of f_0F_2 at other stations than do values of S_I based on Washington data only. The use of 27-day medians in place of monthly medians does not alter the correlation significantly. See also 727 of 1948 and 391 of 1949 (Phillips).

551.510.535 : 523.75 **885**

Observations of Solar and Terrestrial Phenomena during the Mögel-Dellinger Effect (S.I.D.) on 19th Nov. 1949.—R. Müller: O. Augustin & W. Menzel: A. Ehmert: H. Salow: A. Sittkus: W. Dieminger & K. H. Geisweid: J. Bartels. (*J. atmos. terr. Phys.*, 1950, Vol. 1, No. 1, pp. 37–48. In German.) The different authors report respectively on the following phenomena observed at stations in Germany during this sudden ionospheric disturbance: a solar flare of intensity 3; increases of 9·7–20% of cosmic-ray intensity; a radio fade-out accompanied by an increase of the ionization in the E_1, E_2 and F_2 layers; and a terrestrial magnetic solar-flare effect. See also 1911 of 1950 (Ellison & Conway), 2206 of 1950 (Müller) and 3039 of 1950 (Clay & Jongen).

551.510.535 : 523.78 "1947.05.20" **886**

Recombination and Attachment in the F-Region during the Eclipse of 20th May 1947.—J. Savitt. (*J. geophys. Res.*, Dec. 1950, Vol. 55, No. 4, pp. 385–394.) Ionization densities at four heights in the F_2 region are deduced by Manning's method from data obtained during the eclipse at Bocayuva, Brazil. The results are compared with predictions based on simple recombination and attachment hypotheses. Neither hypothesis explains the data completely, the former being slightly better at the lesser heights and the latter at the greater. The better general agreement is obtained with the attachment hypothesis, the coefficient of attachment being consistent with attachment to neutral oxygen atoms. Both coefficients vary considerably with height, and the data indicate that the intensity of ionizing radiation may increase near sunspot groups.

551.510.535 : 535.34 : 621.396.11 **887**

Attenuation of the Extraordinary Component in the Ionosphere E_1 Layer.—W. Becker. (*J. atmos. terr. Phys.*, 1950, Vol. 1, No. 2, pp. 73–81. In German.) The experimental observation that no extraordinary-ray echoes can be received from the normal E layer around sunrise and sunset for frequencies between the gyrofrequency (1·39 Mc/s) and about 2·5 Mc/s, is in accordance with numerical considerations developed. The absence of these echoes is due to the high mean electron-collision frequency, which prevents the real part of the refractive index from reaching a value substantially below unity, a necessary condition for appreciable reflection. In the absence of these echoes, the extraordinary-ray critical frequency of the E_1 layer can be identified as the frequency at which the first echoes are received from a layer at a greater height.

551.510.535 : 535.34 : 621.396.11 **888**

The Absorption of Long and Very Long Waves in the Ionosphere.—Stanley. (See 974.)

551.510.535 : 550.385 **889**

Investigation of the World-Wide Ionospheric Disturbance of 15th March 1948.—O. Burkard. (*Arch. Met. Geophys. Bioklimatol.*, 28th March 1950, Vol. 2, Nos. 2/3, pp. 315–324.) Observations at 30 stations were examined regarding the variations of the F_2-layer critical frequency on the occasion of the geomagnetic storm on the above date. A marked increase of the critical frequency was noted in low geomagnetic latitudes and a decrease in high latitudes. The progress of the main ionospheric disturbance appears to be related to local time.

551.510.535 : 621.396.812.2 **890**

A Study of the Horizontal Irregularities of the Ionosphere.—Briggs & Phillips. (See 980.)

551.510.535 : 621.396.812.3 **891**

Periodic Fading of Short-Wave Radio Signals.—Khastgir & Das. (See 981.)

551.577 : 621.396.9 **892**

Observation of Precipitation with an Airborne Radar.—E. J. Smith. (*Aust. J. sci. Res., Ser. A*, June 1950, Vol. 3, No. 2, pp. 214–223.) Observations were made on a wavelength of 10 cm, using a radar set with its beam directed downwards from an aircraft. Photographic records were obtained of the intensity of the echoes from precipitation. A detailed description is given of observations made during the seeding of a cloud with 'dry ice'. Measurements of the area and duration of precipitation and estimates of precipitation rate below the freezing level and of snowflake size above it were obtained; the rate of fall of the disturbance was also measured. Ice crystals appear to form initially near the bottom of the cloud.

551.578 : 539.16 **893**

On the Radioactivity of Atmospheric Precipitates.—A. Stefanizzi. (*J. geophys. Res.*, Dec. 1950, Vol. 55, No. 4, pp. 373–378.)

551.594.12 **894**

The Ionization Balance of the Atmosphere.—V. F. Hess & R. P. Vancour. (*J. atmos. terr. Phys.*, 1950, Vol. 1, No. 1, pp. 13–25.) Methods for determining the contribution to the total atmospheric ionization made by α, β and γ rays from radioactive substances in the ground and air and by cosmic rays are described, and results of measurements made at Fordham University, N.Y., are reported. The mean number of small ions is computed to be $<100/cm^3$ in the stationary state, as is to be expected near a big city, where the number of condensation nuclei is usually $>40\,000/cm^3$.

LOCATION AND AIDS TO NAVIGATION

621.396.9 : 621.39.001.11 **895**

A Theory of Radar Information.—P. M. Woodward & I. L. Davies. (*Phil. Mag.*, Oct. 1950, Vol. 41, No. 321, pp. 1001–1017.) "The theoretical accuracy and certainty with which range may be determined by radar is obtained quantitatively by applying the principle of inverse probability. In agreement with experience, the theory yields two fundamental criteria for satisfactory radar reception. First, the total received signal energy must always be larger than the effective noise power per unit bandwidth. Secondly, there is a more stringent threshold of unambiguous reception which depends not only on the quantity of received energy but also on the bandwidth of the transmitted waveform, for as this is increased the minimum energy required for the certain detection of an echo also increases. The quantity of information obtainable at the receiver, as measured by reduction of entropy, is evaluated for comparison with that given by Shannon's general theory of communication [1361 and 1649 of 1949]. It is found that as the time of observation and hence the received energy increases, information is initially obtained at a roughly uniform rate which is not far removed from the absolute limit for an ideal communication system, but that after crossing the threshold of unambiguous reception, additional received energy contributes little further information."

621.396.93 **896**

Instantaneous Direction Finding.—J. Rhys Jones. (*Electronic Engng*, Nov. 1950, Vol. 22, No. 273, pp. 481–482.) A historical account of the development of d.f. equipment using c.r. tubes, with descriptions of a prewar and a wartime model. See also 1064 of 1949 (de Walden et al.).

621.396.933 **897**

The Development and Status of Radio Navigational Aids to Civil Aviation.—R. M. Badenach & R. E. Gillman. (*Proc. Instn Radio Engrs, Aust.*, Nov. 1950, Vol. 11, No. 11, pp. 273–283.) The development of radio navigation aids prior to the second world war is described and the effect of that war on the problem is discussed. The present-day status of navigation aids in various countries throughout the world is reviewed. The work of I.C.A.O. in setting the standards for world-wide practice and performance is summarized and plans which have been produced to meet these requirements in U.S.A. and Australia are outlined.

621.396.933 : 526.25 **898**

A Rigorous Method for Computing Geodetic Distance from Shoran Observations.—C. W. Kroll. (*Trans. Amer. geophys. Union*, Feb. 1949, Vol. 30, No. 1, pp. 1–4.) Certain assumptions are made and Anderson's 1941 value of 299 776 km/s for the velocity of light is used. Accurate formulae are derived, but as computation from them is impractical, an approximate method of numerical integration was evolved. This has the advantage that it is an iteration process which can be carried out on an electronic computer in a few seconds.

621.396.933.23 **899**

Einstein's Equivalence Principle and the Problem of Blind Navigation.—J. J. Gilvarry. (*Phys. Rev.*, 1st June 1948, Vol. 73, No. 11, pp. 1409–1410.)

621.396.933.23 **900**

Application of Liouville's Approximation to the Blind Navigation Problem.—J. J. Gilvarry & S. H. Browne. (*J. appl. Phys.*, Nov. 1950, Vol. 21, No. 11, pp. 1195–1196.)

621.396.933 **901**

Consol—a Radio Aid to Navigation (M.C.A.P.59). [Book Notice]—Ministry of Civil Aviation. Publishers: H.M. Stationery Office, London, 2nd edn 1950, 1s. 6d. (*Govt Publ., Lond.*, Sept./Oct. 1950, p. 15.) Brief description of its use, with details of the service and cover provided by existing stations.

MATERIALS AND SUBSIDIARY TECHNIQUES

535.37 **902**

The Behaviour of Phosphors and Photoconductors in Intense Electric Fields.—E. Krautz. (*Z. Naturf.*, July 1949, Vol. 4a, No. 4, pp. 284–296.) The transient enhancement of luminescence produced by applied fields was investigated experimentally for over 250 phosphors, at low temperature, using a specially constructed grating-type cell making field strengths up to 300 kV/cm possible. Oscillograms illustrating the decay of the luminescence after switching the field on or off are shown and discussed; from the shape of the curves it can be judged whether the reaction mechanism is monomolecular or bimolecular. The peak value of the luminescence flash depends on both field intensity and time interval after excitation of the phosphor (e.g., by X-rays).

535.371 **903**

The Influence of Temperature on the Fluorescence of Solids.—F. A. Kröger & W. de Groot. (*Philips tech. Rev.*, July 1950, Vol. 12, No. 1, pp. 6–14.) The theory of the mechanism of fluorescence is outlined and methods for measuring the relative efficiency of fluorescence and its rate of decay after excitation is cut off are described in

detail. Results of measurements for simple cases are compared with deductions from the theory. Effects observed in more complex cases are discussed and examples are given of cases where the efficiency depends not only on temperature but also on the intensity of the incident radiation.

535.371 : [546.321.41+546.341.61 **904**

The Decays of Luminescent KBr and LiF.—A. H. Morrish & A. J. Dekker. (*Phys. Rev.*, 15th Dec. 1950, Vol. 80, No. 6, pp. 1030–1034.) Photomultiplier investigation of luminescence decay after irradiation by X rays, at 21° C and at 0° C.

537.311.33 **905**

Controlled-Valency Semiconductors.—E. J. W. Verwey, P. W. Haaijman, F. C. Romeijn & G. W. van Oosterhout. (*Philips Res. Rep.*, June 1950, Vol. 5, No. 3, pp. 173–187.) "In inorganic solids of a more or less polar type (e.g. oxides) a condition for electronic conductivity is that the lattice contains ions derived from the same element but of different valency in the same crystallographic position. A new type of semiconductor is described in which this condition has been realized by the introduction of a fraction of ions of deviating valency without the simultaneous formation of lattice defects as in 'non-stoichiometric' compounds. Such a situation is promoted by the incorporation into the lattice of foreign ions of such a charge that they balance the charge of the ions of deviating valency. Various examples are given and some of the properties of the materials thus obtained are described. Materials of this type have been applied, for instance, in ceramic resistors having a large negative temperature coefficient of resistance. The influence of various impurities upon the specific resistance of poorly conducting substances or insulators with a crystal lattice of the polar type can also be understood along these lines."

537.311.33 : 537.311.1 **906**

Fermi Levels in Semiconductors.—R. A. Hutner, E. S. Rittner & F. K. du Pré. (*Philips Res. Rep.*, June 1950, Vol. 5, No. 3, pp. 188–204.) "General formulae for determining the Fermi level and the density of free charge carriers in semiconductors are derived. Special semiconductor models are considered in detail and a few applications are discussed."

537.311.33 : 621.315.592† : 546.28.261 **907**

On the Mechanism of Impurity-Band Conduction in Semiconductors.—C. Erginsoy. (*Phys. Rev.*, 15th Dec. 1950, Vol. 80, No. 6, pp. 1104–1105.) The anomalous low-temperature effects on the resistivity and Hall coefficient of SiC are interpreted on the basis of a conduction mechanism in an impurity band formed by the interaction of the excited impurity states at high concentrations.

537.311.33 : 621.315.592† : 621.396.645 **908**

The Amplification Observed in Semiconductors.—Mataré. (See 1037.)

537.311.33 : 621.315.592† : 621.396.822 **909**

Statistical Fluctuations in Semiconductors.—H. F. Mataré. (*Z. Naturf.*, July 1949, Vol. 4a, No. 4, pp. 275–283; *J. Phys. Radium*, Dec. 1949, Vol. 10, No. 12, pp. 364–372, & March 1950, Vol. 11, No. 3, pp. 130–140.) The analogy between barrier layer and diode is considered. An equivalent steady-state circuit is presented for a semiconductor rectifier, and the equivalent noise source and square of noise voltage are determined. The analytical representation of the barrier-layer noise temperature obtained from measurements on diodes and semiconductors is then introduced, and a practical law is derived for the square of the noise voltage, i.e., the statistical fluctuations.

537.311.33 : 621.315.592† : 621.396.822 **910**

A Theory of Contact Noise in Semiconductors.—G. G. Macfarlane. (*Proc. phys. Soc.*, 1st Oct. 1950, Vol. 63, No. 370B, pp. 807–814.) "A theory of contact noise is described in which the low-frequency noise is attributed to the random movement of adsorbed ions on the surface of a semiconductor from which an electron current is being drawn. Emission of electrons is assumed to take place only at localized patches on the surface and the adsorbed ions are assumed to give rise to a Schottky barrier layer, in which the potential maximum is linearly related to the concentration of ions. Diffusion of the ions over the surface gives rise to random fluctuations in the concentration of ions in a patch, which results in random fluctuations in the height of the potential barrier and the emission current. It is shown that for a circular patch the spectral power density of the noise current varies with mean current j_0 and frequency f as $j_0^2 f^x$ over a small range of frequency and that x varies monotonically from $-0{\cdot}75$ at the lowest frequencies to $-1{\cdot}125$ at the highest frequencies. It is also shown that for a long thin rectangular patch the index x varies monotonically from $-0{\cdot}5$ to $-1{\cdot}5$ as the frequency is increased from zero. The dependence of the noise power density on temperature is also discussed."

537.311.33 : 621.315.592.011.2† **911**

Effect of Isolated Lattice Irregularities on the Electrical Resistance of Electronic Semiconductors and its Temperature Dependence.—W. Heywang. (*Z. Naturf.*, Dec. 1949, Vol. 4a, No. 9, pp. 654–664.)

538.221 **912**

Ferromagnetic Materials and Ferrites: Properties and Applications.—M. J. O. Strutt. (*Wireless Engr*, Dec. 1950, Vol. 27, No. 327, pp. 277–284.) The parameters controlling the properties of ferrites and other ferromagnetic materials are summarized and the relations between the Q value of a cored inductor, core size, hysteresis distortion and saturation limitations are discussed for commercially available core materials. The conditions giving optimum performance are indicated and the possibilities of obtaining small, highly efficient transformers for low-power applications by using ferrite cores are stressed. The very low hysteresis and eddy-current losses with these materials, when used correctly, give a better approximation to an ideal transformer for the lower r.f. bands than do other core materials.

538.221 **913**

High-Frequency Permeability of Ferromagnetic Materials.—R. Millership & F. V. Webster. (*Proc. phys. Soc.*, 1st Oct. 1950, Vol. 63, No. 370B, pp. 783–795.) Measurements of the resistive and inductive permeabilities in the range 150 Mc/s to 10 kMc/s were made using a coaxial line with the inner conductor made from the material under investigation. At all frequencies the resistive permeability μ_R is greater than the inductive permeability μ_L; the effective permeability is assumed to be complex and is plotted as a function of μ_R and μ_L against frequency.

538.221 : 538.24 **914**

Thermal Effects due to Magnetization Processes in Weak Fields.—L. F. Bates. (*J. Phys. Radium*, Dec. 1949, Vol. 10, No. 12, pp. 353–363.) Paper given at a meeting of the French Physical Society, describing experimental research carried out at the University of Nottingham. Measurements on Ni, Fe, Co and various alloys are reported, and specially devised apparatus is described. A

quantitative interpretation of the results has been put forward tentatively by Stoner and Rhodes. An account is included of experiments undertaken to verify theories of Néel and of Lawton & Stewart on the structure of the elementary domains in monocrystals; equidistances in agreement with a formula given by Néel were found.

538.221 : 669.74.018 **915**

Ferromagnetic Interactions in Manganese Alloys.—L. Castelliz & F. Halla. (*Acta phys. austriaca*, Feb. 1949, Vol. 2, Nos. 3/4, pp. 348–355.)

538.652 **916**

Reversal of Sign of Magnetostriction by Expansion.—W. Braunewell & E. Vogt. (*Z. Naturf.*, Oct. 1949, Vol. 4a, No. 7, pp. 491–495.)

546.431.42-31 : 536.2.022 **917**

Thermal Conductivity of Barium/Strontium Oxide.—G. F. Weston. (*Nature, Lond.*, 30th Dec. 1950, Vol. 166, No. 4235, pp. 1111–1112.) Earlier experimental values are criticized and details are given of measurements using a method based on Lees' disk. Preliminary results indicate values of $1–5\times10^{-6}$ cal deg^{-1} cm^{-1} sec^{-1} at 1000° K, increasing slightly with temperature. The results appear independent of the compression of the original carbonate, and of the state of activation of the oxide.

546.431.824 : 537.228.1 **918**

The Electromechanical Behaviour of $BaTiO_3$ Single-Domain Crystals.—M. E. Caspari & W. J. Merz. (*Phys. Rev.*, 15th Dec. 1950, Vol. 80, No. 6, pp. 1082–1089.) The d_{31} piezoelectric coefficient was measured by both a static and a dynamic method and its value compared with that theoretically derived from the permittivity and spontaneous polarization. Measurements were made from room temperature to 140° C (Curie point 120° C). The static method, contrary to the dynamic method, shows that d_{31} is not zero above the Curie point but that it decreases slowly with increasing temperature. This effect is attributed to the tetragonal structure induced by the external field through the electrostrictive effect. Observations of optical birefringence confirm this hypothesis.

546.842.221 : 537.58 **919**

Thorium Sulfide as a Thermionic Emitter.—T. E. Hanley. (*J. appl. Phys.*, Nov. 1950, Vol. 21, No. 11, p. 1193.) The emission from ThS is only a quarter of that from ThO_2 at a brightness temperature of about 1 500° C.

548.0 : 537.228.1 **920**

Growing Piezoelectric Crystals.—A. C. Walker. (*J. Franklin Inst.*, Dec. 1950, Vol. 250, No. 6, pp. 481–524.) A summary of work carried out at the Bell Telephone Laboratories on the growing of large single crystals of ADP, EDT and quartz. Basic principles are indicated and apparatus is described. Problems encountered in the pilot-plant stage of the commercial production of ADP and EDT crystals are discussed.

549.514.51 : 537.228.1.096 **921**

The Variation with Temperature of the Piezoelectric Coefficients of Quartz.—A. C. Lynch. (*Proc. phys. Soc.*, 1st Nov. 1950, Vol. 63, No. 371B, pp. 890–892.) "The equivalent electrical circuits of three bars in longitudinal vibration were measured at approximately 25, 52·5 and 80° C. In this range of temperature the temperature coefficients of d_{11} and d_{14} are respectively -2_{30} and $+13_{80}$ parts/million/°C, and there is no evidence to support Cady's suggestion that d_{11} passes through a maximum near room temperature. The measurements suggest a rather high value for d_{14}: $(-2{\cdot}21\pm0{\cdot}1)\times10^{-8}$ cm/e.s.u. of potential at 25° C."

621.3.013.24 **922**

The Production of Pulsed Magnetic Fields, using Condenser Energy Storage.—K. S. W. Champion. (*Proc. phys. Soc.*, 1st Oct. 1950, Vol. 63, No. 370B, pp. 795–806.) The pulsed magnetic field obtained by discharging a capacitor through an air-cored coil is investigated theoretically, and expressions and curves are derived which enable the field produced by a specified coil and capacitor combination to be readily calculated. A switch, preferably electronic, connects the coil to the capacitor to initiate the discharge and then disconnects the two exactly at the end of one cycle. Thus all the stored energy is used to produce the field, and most of it is recovered at the end of the pulse. Coil design is considered in detail and a description is given of a practical air-cooled coil producing a field of 22·7 kilogauss with pulse duration 10·7 ms, when used with an 8-μF capacitor fed from a 25-kV source. See also 90 of 1950 (Raoult).

621.3.066.6 : 621.775.7 **923**

Electrical Contacts and Powder Metallurgy.—N'Guyen Thien-Chi. (*Ann. Radioélect.*, Oct. 1950, Vol. 5, No. 22, pp. 339–353.) Powder metallurgy has particularly valuable possibilities for the production of sintered electrical contacts. Some pseudo-alloys specially useful in this field are discussed, e.g., W (or Mo)/Cu (or Ag), Ag/CdO (or Ni, graphite, etc.), and figures for ductility and malleability are reported. Since in a pseudo-alloy each constituent retains its individual nature, the resulting range of properties far exceeds that obtainable with classical metallurgical processes. See also 2817 of 1949.

621.314.63 **924**

Nonuniform Distributions of Impurity Centres in Dry Rectifiers.—E. Spenke. (*Z. Naturf.*, April 1949, Vol. 4a, No. 1, pp. 37–51.) Typical distributions of impurity centres are investigated in a search for effects related to variation of concentration with distance from counter-electrode. The current/voltage relation is presented in a convenient approximate form whose evaluation demands only a knowledge of the potential variation through the barrier layer; this variation is determined for any distribution of impurity centres. The relation between the distribution of impurity centres and the dependence of differential resistance on bias voltage is studied for both backward and forward directions.

621.314.632.1.011.5 **925**

The Dielectric Properties of Copper-Oxide Rectifiers.—J. H. Calderwood, R. Cooper & H. K. Heppel. (*Research, Lond.*, Nov. 1950, Vol. 3, No. 11, pp. 530–531.) Using an impedance-bridge circuit, measurements of barrier-layer capacitance and differential resistance were made at frequencies between 100 c/s and 10 kc/s on a number of Cu_2O rectifiers. Both quantities varied somewhat with frequency. Loss-angle values showed general agreement with the Debye absorption curve. Over the range 0°–40° C, a shift of absorption to lower frequencies with decreasing temperature was observed.

621.314.634 **926**

A Study of Electrical Forming Phenomena at Selenium Contacts.—H. K. Henisch & J. Ewels. (*Proc. phys. Soc.*, 1st Nov. 1950, Vol. 63, No. 371B, pp. 861–876.) An account is given of current-creep experiments at various temperatures on Se specimens of different impurity content. Two opposing creep mechanisms are, in general, active simultaneously. A theory of current creep is outlined.

621.315.612.4 : 546.815.824 **927**

X-Ray Study of the Phase Transition in Lead Titanate.—G. Shirane, S. Hoshino & K. Suzuki. (*Phys. Rev.*, 15th Dec. 1950, Vol. 80, No. 6, pp. 1105–1106.) Measurements

in the range −170° to +550° C indicate a change from tetragonal to cubic structure at the Curie temperature, about 490° C.

621.315.617.3 **928**

Insulating Varnishes.—H. Quillatre. (*Electrician*, 1st Dec. 1950, Vol. 145, No. 3781, pp. 1249–1253.) The physical and chemical properties required in insulating varnishes are enumerated and a survey is made of the various materials that are available, including silicones and high-temperature resins. The uses of varnishes on electrical and radio components and the methods of application are discussed in some detail.

666.1.037.5 **929**

The Physical Aspect of Glass/Metal Sealing in the Electronic Valve Industry: Part 3.—G. Trébuchon & J. Kieffer. (*Ann. Radioélect.*, Oct. 1950, Vol. 5, No. 22, pp. 407–418.) The influence of shape parameters on strains in seals is studied for two particular glass/metal combinations; the importance is emphasized of relating the strains in industrial-type seals to those in standard test seals. External factors affecting seals include annealing conditions, humidity, electrical effects and thermal shock. Maximum tolerable strains are determined, taking account of production economics. The results of the investigation are applied as a basis for industrial specifications covering annealing cycles, properties required in new glasses for sealing to metals and inspection of seals. Part 2: 135 of January.

MATHEMATICS

517.4/.5 **930**

The Use of Symbolic Calculus in Mathematical Research.—S. Colombo. (*Ann. Télécommun.*, Oct. 1950, Vol. 5, No. 10, pp. 347–364.) Theoretical bases of the technique are summarized and its possible applications in establishing relations characteristic of certain transcendental functions are studied, including Hankel's transformation and higher-order circular and hyperbolic functions. Its use in the study of certain mass distributions and in van der Pol's applications to the analytical theory of numbers is described; other examples of its application are indicated. Symbolic calculus is a useful research tool; its rules are straightforward and rigorous and define necessary, if not always sufficient, conditions of validity. Forty-nine references are given.

517.422 **931**

The Mellin Transform and its Applications.—P. A. Barrucand. (*Ann. Télécommun.*, Nov. 1950, Vol. 5, No. 11, pp. 381–388.) This transformation, though not so well known as that of Laplace, is one of the most important in mathematics. The principal rules of operation are studied and the transformation is applied to various problems, including the formation of Fourier kernels and the analytical extension of Taylor's series. An appendix gives numerous transformation formulae.

517.432.1 **932**

A Derivation of Heaviside's Operational Calculus Based on the Generalized Functions of Schwartz.—J. J. Smith & P. L. Alger. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part II, pp. 939–944. Discussion, pp. 944–946.) Full paper. Summary noted in 1182 of 1950.

519.272 **933**

The Statistics of Correlated Events: Part 1.—C. Domb. (*Phil. Mag.*, Oct. 1950, Vol. 41, No. 321, pp. 969–982.) One effect of the correlation of events is a change in the mean-square deviation of the number of events occurring in an interval of time t. By analogy with the shot effect in the presence of space charge, this is denoted by a factor Γ^2 for large values of t, and Γ^2 is evaluated in terms of the interval distributions between events. For finite intervals t a corresponding factor $\gamma^2(t)$ is introduced which usually tends toward 1 as $t \to 0$. A correlation function for events occurring at times separated by an interval τ is defined, and its relation to $\gamma^2(t)$ is discussed. A generalization of Campbell's theorem applying to correlated events is derived and the problem of the random partitioning of correlated events is discussed.

621.385.832 : 517.51 : 681.142 **934**

The Monoformer.—Munster. (See 1033.)

517.512.4 **935**

Table of the Bessel Functions $Y_0(z)$ and $Y_1(z)$ for Complex Arguments. [Book Review]—Computation Laboratory, National Bureau of Standards. Publishers: Columbia University Press, New York, 1950, 1427 pp., $7.50. (*J. Franklin Inst.*, Dec. 1950, Vol. 250, No. 6, pp. 587–588.) The functions are tabulated for complex arguments defined in polar coordinates along each of the rays $\Phi = 0°, 5°, \ldots 90°$; ten-place values of the real and imaginary parts are given for values of $|z|$ from 0 to 10 at intervals of 0·01. Various auxiliary tables and an explanatory introduction are included.

681.142 **936**

Calculating Instruments and Machines. [Book Review]—D. R. Hartree. Publishers: University of Illinois Press, Urbana, Ill., and Cambridge University Press, London, 1949, 138 pp., 21s. (*Nature, Lond.*, 30th Dec. 1950, Vol. 166, No. 4235, p. 1087.) "A very welcome addition to the literature of the subject."

681.142 **937**

High-Speed Computing Devices. [Book Review]—Engineering Research Associates. Publishers: McGraw-Hill Book Co., New York, 1950, 451 pp., $6.50. (*J. Franklin Inst.*, Dec. 1950, Vol. 250, No. 6, p. 583.) The book is in three parts, dealing respectively with basic elements of machine computation, computing systems, and physical components and methods. The first and last parts deal primarily with electronic equipment, while the second part describes machines of all types. An extensive bibliography is integrated into the subject matter. Recommended to designers, users, and students.

MEASUREMENTS AND TEST GEAR

53.087.6 : 529.78 : 53.088 **938**

Rate Drift of Timepieces.—(*Tech. Bull. nat. Bur. Stand.*, Oct. 1950, Vol. 34, No. 10, pp. 150–151.) Short account of equipment developed by H. A. Bowman. A relay-type servo system keeps the phase of a crystal-controlled frequency standard in step with the frequency of the timepiece or oscillator under test. The magnitude of the phase shift is automatically plotted against time.

621.317.3 : 621.396.611.3 **939**

Principles of Measurements on Coupled Circuits.—W. F. Dil. (*Philips Res. Rep.*, June 1950, Vol. 5, No. 3, insertion slip.) Corrections to article abstracted in 393 of February.

621.317.335.2 : 621.314.63 **940**

A New Method of Capacity Measurement on Dry Disk Rectifiers.—K. Lehovec. (*J. appl. Phys.*, Jan. 1949, Vol. 20, No. 1, p. 123.) With an a.c. voltage and a suitable d.c. bias applied to the rectifier in series with a small resistor, the characteristic is traced on a c.r.o., using the voltage across the rectifier to give the abscissa and that across the resistance to give the ordinate. The character-

istic shows a loop from which the capacitance and resistance can be calculated as a function of voltage, assuming that (*a*) the rectifier is equivalent to a capacitance shunted by a resistance, and (*b*) both are functions of the instantaneous voltage only.

621.317.335.2 : 621.314.63 **941**

An Oscillographic Method for the Investigation of Dry-Rectifier Barrier Layers.—A. Hoffmann. (*Z. angew. Phys.*, 15th Sept. 1950, Vol. 2, No. 9, pp. 353–359.) The assumptions and limitations of Lehovec's oscillographic 'loop' method of determining barrier-layer capacitance (940 above) are examined in detail. The discussion is restricted to disk-type rectifiers. Measurements made by this method are in good agreement with reactance-bridge measurements; the loop method has the advantage in respect of speed and ability to deal with incomplete rectifier disks, but is unsuitable for work at low values of forward current, on account of unavoidable large errors.

621.317.352 : 621.396.611.4 **942**

Simple Method for Measurement of Variations of Damping of Centimetre Waves.—Philipp. (See 841.)

621.317.4 : 621.318.2 **943**

Measurements on Ring-Gap Magnets.—E. Schäfer. (*Funk u. Ton*, Oct. 1950, Vol. 4, No. 10, pp. 519–524.) Leakage flux associated with the gap is calculated to a close approximation and a ballistic method of measuring the flux density in the gap is described.

621.317.444† **944**

General Theory, and Experimental Confirmation, of the Moving-Coil Fluxmeter.—T. J. Higgins & G. Robertson. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part II, pp. 897–907. Discussion, pp. 907–908.) An inclusive mathematical theory of the operation of the unshunted fluxmeter is developed. Experimental results confirm the general theory. Analogous theory and experimental results are also given for the shunted type of meter.

621.317.7 : 621.316.8 : 621.396.822 **945**

The Measurement of Noise in Resistors.—F. Oakes. (*Electronic Engng*, Nov. 1950, Vol. 22, No. 273, pp. 464–469.) The resistor under test is connected to the input terminals of a calibrated a.f. high-gain feedback amplifier, whose output circuit includes either a thermocouple and r.m.s. meter, a peak voltmeter, a diode detector circuit, or a c.r.o. for monitoring or recording purposes. Precautions necessary, the various types of resistor noise, and the measurement of noise in variable resistors, are discussed. A mixer and filters are used with the amplifier to investigate the frequency distribution of noise.

621.317.7 : 621.392.26† **946**

A Measuring Arrangement for Waveguides.—A. E. Pannenborg. (*Philips tech. Rev.*, July 1950, Vol. 12, No. 1, pp. 15–24.) Description of equipment used in the Philips laboratories for determining reflection coefficients from measurements of voltage s.w.r. in a waveguide. Accessories include a microwave generator, directional couplers, an attenuator, a crystal rectifier, and a wavemeter of the cavity-resonator or transmission-line type.

621.317.725 **947**

A New Electrostatic Voltmeter.—H. Greinacher. (*Bull. schweiz. elektrotech. Ver.*, 15th Oct. 1949, Vol. 40, No. 21, pp. 816–817. In German.) If two metal plates are partly immersed close together in a liquid dielectric, the meniscus rises when a potential difference is applied across the plates. Two voltmeters based on the simple relation existing between the rise of level and the applied potential difference are described, one for microscope reading and the other with a projection scale. The effect has been applied previously for the determination of dielectric constant (see *Helv. phys. Acta*, 1948, Vol. 21, Nos. 3/4, pp. 261–272).

621.317.733 : 535.416 **948**

Standing Wave Ratio Bridge.—R. W. Caywood & R. A. Bradbury. (*FM-TV*, Nov. 1950, Vol. 10, No. 11, pp. 19–50.) A description of the Millen r.f. bridge, designed primarily for s.w.r. measurements at frequencies between 1·5 Mc/s and 42 Mc/s. Applications to problems of matching transmitters and receivers to transmission lines and aerials are indicated.

621.317.755 : 621.3.029.5/.6 **949**

A Cathode-Ray Oscillograph for Periodic Phenomena of High Frequencies.—J. M. L. Janssen. (*Philips Res. Rep.*, June 1950, Vol. 5, No. 3, pp. 205–240.) A system of electronic stroboscopic scanning of the signal is obtained by mixing it with phase-modulated pulses. The design of the pulse generator and the mixer and synchronization circuits is discussed in detail. The technique has been used for the observation of distorted signals with harmonics up to 30 Mc/s, for the measurement of phase and amplitude characteristics up to 70 Mc/s and for the observation of modulated signals with carrier frequencies up to 70 Mc/s and modulation frequencies up to 20 kc/s.

621.317.763 **950**

The Michelson Interferometer at Millimetre Wavelengths.—W. Culshaw. (*Proc. phys. Soc.*, 1st Nov. 1950, Vol. 63, No. 371B, pp. 939–954.) The design and operation of an instrument working at a wavelength of 12·5 mm is described. The transmitting and receiving apertures are 6 in. square horns, both partially corrected by metal lenses to give an approximation to plane-wave operation. The beam divider consists of two $\lambda/4$ polystyrene plates separated by an adjustable air gap. Wavelength measurements were made with various path lengths; the results are most accurate when working well inside the Fraunhofer diffraction region. The measured wavelength increases as the spacing is reduced.

The frequency of the source is stabilized by a high-Q cavity used as an r.f. discriminator. The frequency was measured with a calibrated frequency meter and the resulting velocity of e.m. waves agrees, within the accuracy of the instrument (1 part in 10^4), with the accepted value. The interferometer has also been used to measure the dielectric constant of low-loss materials, and its use as a substandard of length is discussed.

621.396.615.015.7† **951**

A Pulse Generator for the Millimicrosecond Range.—R. L. Garwin. (*Rev. sci. Instrum.*, Nov. 1950, Vol. 21, No. 11, pp. 903–904.) Describes a laboratory generator of pulses with rise and decay times $< 2 \times 10^{-10}$ sec at a repetition rate of 120/sec. A mechanical switch in the centre conductor of a coaxial line is operated by a 60-c/s magnetic field in an external coil. Three simultaneous outputs are available, variable in amplitude from 100 μV to 100 V.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

531.787.6 : 621.38 **952**

Diaphragm-Type Micromanometer with Electronic Pickup.—(*Tech. Bull. nat. Bur. Stand.*, Oct. 1950, Vol. 34, No. 10, pp. 137–139.) Movement of the diaphragm in response to pressure variations is measured by a mutual-inductance micrometer [see 696 of March (Gordon & Richmond)].

534.321.9 : 620.179.16 **953**

Application of Ultrasonics in the Testing of Materials.—L. Bergmann. (*Z. Ver. dtsch. Ing.*, 1st Sept. 1950, Vol. 92, No. 25, pp. 711–718.) A review is given of the development of ultrasonic testing apparatus in the two main classes operating respectively by transmission and reflection; the advantages and drawbacks of the two systems are compared. The theoretical basis is given briefly, and commercial apparatus is described. An application still in an early stage is the study of the crystalline structure of materials. Twenty-five references are listed.

621.314.653 **954**

The Ignitron and its Applications.—David & Caussin. (See 1015.)

621.316.578.1 **955**

Electronic Sequence Timing for Compression-Molding Presses.—J. H. Wyman. (*Elect. Mfg, N.Y.*, Nov. 1948, Vol. 42, No. 5, pp. 114–116.) Details of the construction and mode of operation of a 4-stage sequence timer. This controls the setting of two 3-way valves and two 2-way valves which directly govern the air supply to the press.

621.316.578.1 : 621.385.38 **956**

Timing Machine Operations with Small Thyratrons.—S. C. Rockafellow. (*Product Engng*, Nov. 1950, Vol. 21, No. 11, pp. 85–90.) Descriptions and diagrams of circuits for introducing time delay into the control systems of automatic and semi-automatic machines such as presses and test gear.

621.316.74 : 621.385.38 **957**

Precision Thermostat for High Temperatures.—(*J. Franklin Inst.*, Nov. 1950, Vol. 250, No. 5, pp. 443–445.) Short description of a thermostat developed at the National Bureau of Standards by W. R. Eubank. The resistance of the Pt/Rh wire used for the furnace heater winding changes rapidly with temperature above 1 000°C; this winding forms one arm of an a.c. bridge, the unbalance voltage from which is amplified and applied to the control grid of a thyratron controlling the current supplied to the heater coil. Furnace temperatures in the range 1 000°–1 550°C are maintained constant within ±0·1°C for several hours and within ±1·0°C for several days.

621.318.4 : 621.365.54† **958**

Work-Coils for H.F. Heating.—R. A. Whiteman. (*Radio & Televis. News, Radio-Electronic Engng*, Oct. 1950, Vol. 15, No. 4, pp. 3A–6A, 28A.) Theory and practice are combined to obtain the optimum design of work coils for induction heating.

621.365.54/.55† **959**

The Design of H.F. Generators for Industrial Use and the Development of their Application in France.—J. Girardeau. (*Onde élect.*, Nov. & Dec. 1950, Vol. 30, Nos. 284 & 285, pp. 488–496 & 542–546.) See 178 of January.

621.365.54† **960**

Some Possibilities of H.F. Induction Heating in the Surface Hardening of Motor-Car Parts.—J. J. Leven. (*Ann. Radioélect.*, Oct. 1950, Vol. 5, No. 22, pp. 419–432.) An account is given of h.f. generating plant and semi-automatic hardening equipment in industrial use. Results obtained with typical parts are reported.

621.384.611.1† **961**

Ejection of the Electron Beam from a Betatron.—S. L. Fawcett & E. C. Crittenden, Jr. (*Rev. sci. Instrum.*, Nov. 1950, Vol. 21, No. 11, pp. 935–936.) Modification of scheme proposed by Crittenden & Parkins (3438 of 1946).

621.384.611.2† **962**

Synchrotron-Oscillation Resonance.—N. M. Blachman. (*Rev. sci. Instrum.*, Nov. 1950, Vol. 21, No. 11, pp. 908–911.)

621.384.62 + 621.385.029.63/.64 **963**

The Control of Electron Streams by means of Progressive Waves (Travelling-Wave Tubes).—Döhler. (See 1017.)

621.385.83 **964**

Note on the Focusing of Electron Beams in Certain Magnetic Fields.—P. A. Sturrock. (*Proc. phys. Soc.*, 1st Nov. 1950, Vol. 63, No. 371B, pp. 954–957.) "Equations are set out which determine the focusing properties of electron beams in magnetic fields whose scalar potential has a plane of antisymmetry. From these is derived the condition that a proposed ray-axis and associated focusing requirements should be physically realizable. It is also shown that the fringe-effect of fields with sharply defined boundaries may be characterized by a pair of focal lengths, for which formulae are given."

621.385.833 **965**

A Small Electron Microscope.—J. H. Reisner & E. G. Dornfeld. (*J. appl. Phys.*, Nov. 1950, Vol. 21, No. 11, pp. 1131–1139.) The instrument has a resolution of 100 Å. The magnetic lenses are energized by permanent magnets; the accelerating voltage is 50 kV, variable by 500 V for focusing. Plates and specimens can be rapidly changed. Direct magnifications of 1 500, 3 000 and 6 000 are available.

621.385.833 **966**

Electron Scattering and Image Formation in the Electron Microscope.—B. v. Borries. (*Z. Naturf.*, April 1949, Vol. 4a, No. 1, pp. 51–70.)

621.387.4† **967**

Statistical Limitations on the Resolving Time of a Scintillation Counter.—R. F. Post & L. I. Schiff. (*Phys. Rev.*, 15th Dec. 1950, Vol. 80, No. 6, p. 1113.) Discussion of the limitations on resolving time that arise from fluctuations in the emission, transmission, and collection of scintillation photons.

621.387.4† **968**

A Study of the Deterioration of Methane-Filled Geiger-Müller Counters with External Cathode.—D. Blanc. (*J. Phys. Radium*, Dec. 1949, Vol. 10, No. 12, pp. 411–414.) A useful life ranging from 6×10^7 to 2×10^8 impulses is observed. The limitation of life is due to deposition of material on the cylinder, with consequent reduction of its work function.

621.387.4† : 621.383 **969**

Multiplier Phototubes in Scintillation Counters.—Hickman. (See 1016.)

621.395.625.3.029.42 : 611.81 **970**

Magnetic-Tape Recorder for Very-Low-Frequency Phenomena.—P. E. Green, Jr. (*Rev. sci. Instrum.*, Nov. 1950, Vol. 21, No. 11, pp. 893–895.) Equipment for recording electrical 1–100-c/s signals for subsequent reproduction. The signals are used to modulate the frequency of a 1-kc/s carrier wave. The tape speed for reproduction is five times the recording speed, so that the output from the demodulator gives the original signals with frequencies multiplied by 5.

PROPAGATION OF WAVES

538.566.2 **971**

Research on the Propagation of Sinusoidal Electromagnetic Waves in Stratified Media: Application to Thin Layers: Part 1.—Abelès. (See 857.)

621.396.11 **972**

Group and Phase Velocities from the Magneto-ionic Theory.—H. A. Whale & J. P. Stanley. (*J. atmos. terr. Phys.*, 1950, Vol. 1, No. 2, pp. 82–94.) "When a radio wave is transmitted through a medium consisting of free electrons it is well known that the product of the refractive index μ and the 'group refractive index' μ' is equal to unity. When a steady magnetic field is imposed on the medium, μ becomes a complicated function of wave frequency and the direction of propagation, μ' is even more complicated and the product $\mu\mu'$ is no longer equal to unity. It is shown that it is then convenient to consider values of the product $\mu\mu'$ for different frequencies and directions of propagation, and sets of curves are given from which the behaviour of this product can be visualized as both wave-frequency and direction of propagation are varied. The curves were computed by the use of the EDSAC electronic computer. The use of the curves and the conditions under which they may be applied are discussed briefly."

621.396.11 : 532.517.4 : 551.510.5 **973**

Scattering of Electromagnetic Waves by Atmospheric Turbulence.—E. C. S. Megaw. (*Nature, Lond.*, 30th Dec. 1950, Vol. 166, No. 4235, pp. 1100–1104.) Information concerning the large-eddy end of the spectrum of turbulence in the free atmosphere, obtained from analysis of records of angular fluctuations of star images, and concerning the small-eddy end of the spectrum, derived from observations of stellar brightness fluctuations, is discussed. Consistency of the values of total fluctuation of refractive index derived from these two sources indicates that it is correct to assume that "all the observations can be accounted for by an average spectrum of turbulence which is a permanent characteristic of the atmosphere, and that this is, in fact, the Kolmogoroff spectrum."

Formulae resulting from a theory of scattering of short radio waves are quoted and differences between results deduced from this theory and from that of Booker & Gordon (1757 of 1950) are discussed. Theoretical results are compared with observations of field strengths of 10-cm waves on oversea and overland paths; these apparently confirm that "turbulent scattering, at least of centimetre waves, represent a permanent, if slightly variable, modification of normal propagation beyond the horizon."

621.396.11 : 535.34 : 551.510.535 **974**

The Absorption of Long and Very Long Waves in the Ionosphere.—J. P. Stanley. (*J. atmos. terr. Phys.*, 1950, Vol. 1, No. 2, pp. 65–72.) "Experimental observations on a series of low frequencies have been used to show that models of the ionosphere in which the ionization density increases linearly or parabolically with height are unsuitable for explaining long and very-long-wave reflection phenomena. Agreement with observation can however be obtained if an absorbing or D-region of small ionization density but several kilometres in thickness is assumed to lie below the main reflecting region. A model in which the ionization density increases exponentially with height is found to include such an absorbing region; this model is used to deduce values for the ionization gradient and the electronic collision frequency in the very-long-wave reflecting region."

621.396.11 : 535.34 : 551.510.535 **975**

Attenuation of the Extraordinary Component in the Ionosphere E_1 Layer.—Becker. (See 887.)

621.396.11 : 551.510.535 **976**

Notes on the Ionosphere Reflection Coefficient — Scattering of Ground Wave and its Conversion into Space Wave.—C. Glinz. (*Tech. Mitt. schweiz. Telegr.-Teleph-Verw.*, 1st June 1950, Vol. 28, No. 6, pp. 224–228. In French.) French version of paper noted in 1221 of 1950.

621.396.11 : 621.396.812.4 **977**

Comparison of Tropospheric Reception at 44·1 Mc/s and at 92·1 Mc/s over the 167-Mile Path, Alpine, New Jersey, to Needham, Massachusetts, 1947–1948.—G. W. Pickard & H. T. Stetson. (*J. atmos. terr. Phys.*, 1950, Vol. 1, No. 1, pp. 32–36.) Extended version of paper presented at the International Council of Scientific Unions, Oslo, Aug. 1948. Daily measurements of field intensity are analysed. The two transmitting aerials are on the same tower and radiate approximately equal power on the horizon. The records for the two transmissions show similar daily and monthly variations, both of which can be correlated with atmospheric refraction as determined by calculation from surface meteorological data at Boston. This correlation suggests a common mode of propagation for the two transmissions, the results indicating that the main mode is by refraction in the lower atmosphere rather than by reflection or by ducts.

621.396.11.029.5 **978**

A Study of Ionospheric Ray Field Intensity in the 10–30 and 500–1 100 kc/s Bands.—K. W. Tremellen. (*Marconi Rev.*, 4th Quarter 1950, Vol. 13, No. 99, pp. 153–167.) A re-examination of data recorded in 1922-23 and 1933-34 in the light of present-day knowledge of the ionosphere. The data have been analysed in relation to season, time of day, latitude, sunspot and magnetic activity, direction of propagation, and polarization. Differences in field strength were noted for oversea and overland paths, and signals at low frequencies were often received from distant stations by both round-the-world paths. Consistent results were obtained over daylight paths, but the propagation phenomena over paths partly or wholly in darkness were variable and have not been satisfactorily explained.

621.396.11.029.63(494) **979**

Observations on the Propagation of Decimetre Waves in Switzerland.—J. Dufour. (*Tech. Mitt. schweiz. Telegr.-TelephVerw.*, 1st Nov. 1950, Vol. 28, No. 11, pp. 417–422. In French.) Paper presented at the U.R.S.I. congress at Zürich, September 1950. Field-strength measurements were made over a period of nearly two years on a wavelength of 96 cm, using a 30-W transmitter at Chasseral in the Jura, 1 610 m above sea level, and receivers at Geneva, Uetliberg, Gurten and the Jungfraujoch. The profiles of these paths are illustrated; all afford uninterrupted 'vision'. Correlation of observations at the different receivers is found only for large-scale variations. Maximum, minimum and mean values were noted for 2-hr periods; the results were analysed statistically, and are shown diagrammatically and discussed in relation to seasonal, time-of-day and atmospheric-refraction effects. The unexpected unreliability of the Jungfraujoch path seems to indicate that for steady reception the path should include features capable of eliminating multipath effects due to ground reflections.

621.396.812.2 : 551.510.535 **980**

A Study of the Horizontal Irregularities of the Ionosphere.—B. H. Briggs & G. J. Phillips. (*Proc. phys. Soc.*, 1st Nov. 1950, Vol. 63, No. 371B, pp. 907–923.) The theory of diffraction by a random screen developed by Booker, Ratcliffe & Shinn (428 of February) is presented in a convenient form for practical application in ionospheric experiments. It is shown that measurements of the correlation of the fading of the reflected wave observed at spaced receiving points can be used to find the extent of the angular spreading of the downcoming wave. Histograms are given to show the frequency of occurrence of different degrees of angular spreading observed during a series of experiments using pulse transmissions at vertical incidence. For a frequency of 2·4 Mc/s it is most common to find that the downcoming wave has an angular

spread such that the amplitude falls to half value at an angle of 5° for regions E and F. For a frequency of 4·8 Mc/s, the corresponding value for region F is 2·5°. There is no evidence for any pronounced seasonal or diurnal variations.

621.396.812.3 : 551.510.535 **981**

Periodic Fading of Short-Wave Radio Signals.—S. R. Khastgir & P. M. Das. (*Proc. phys. Soc.*, 1st Nov. 1950, Vol. 63, No. 371B, pp. 924–930.) Periodic fading of c.w. signals of frequency 4·84 Mc/s over a distance of 240 km was observed in India during the evening and early-night hours of December 1948 and January 1949. The two main types of periodic fading were (*a*) sinuous fading at 25–60 cycles/min, attributed to interference between the lower- and upper-trajectory extraordinary waves reflected from the E region, and (*b*) periodic fading at 2–10 cycles/min, attributed to interference between the two waves singly and doubly reflected from the F_2 region or singly reflected from regions E and F_2. This could be accounted for by a vertical drift of the ionospheric layer or layers, at a rate agreeing with observed values. These two types of fading were sometimes superimposed. In a few patterns there was evidence of frequencies of 4–12 c/s, the origin of which is unknown.

RECEPTION

621.396.621 **982**

An Up-to-Date, High-Fidelity Receiver using Modern Valves: Part 2—The High-Frequency Circuits, Power Supply, and Complete Arrangement.—J. Rousseau. (*T.S.F. pour Tous*, Dec. 1950, Vol. 26, No. 266, pp. 409–416.) One stage of h.f. amplification is provided, using a 6BA6 miniature pentode. In the frequency changer a conversion slope of 1·1 mA/V is obtained using a 6BA6 valve as mixer with a 6J5 valve as oscillator. The wave-selection arrangements provide two short-wave and two medium-wave bands, and one long-wave band. Two 6BA6 valves in push-pull give high gain combined with stability in the i.f. stage, and the three-winding i.f. transformer has a response curve approaching the ideal square-top form. The detector uses a 6H6 double diode. A.g.c. without amplification is provided by means of a three-diode circuit, double diodes being used to suit the balanced system. The visual tuning indicator is a 6AF valve. The power unit uses two GZ40 full-wave rectifiers in parallel, delivering 170 mA. Circuit diagrams with all component details are given. Part 1: 440 of February.

621.396.621.004.67 **983**

Most-Often-Needed 1950 Radio Diagrams and Servicing Information. [Book Review]—M. N. Beitman. Publishers: Supreme Publications, Chicago, 192 pp., $2.50. (*Radio & Televis. News*, Oct. 1950, Vol. 44, No. 4, pp. 126–127.) The tenth volume of this popular servicing series. Includes diagrams and data for sets made by nearly 30 manufacturers. The previous volume was noted in 2317 of 1949.

STATIONS AND COMMUNICATION SYSTEMS

621.39.001.11 **984**

Information Theory.—W. Jackson. (*Nature, Lond.*, 6th Jan. 1951, Vol. 167, No. 4236, pp. 20–22.) An account of the proceedings at a symposium in the rooms of the Royal Society, September 1950, with short summaries of the various papers presented. Applications for copies of the proceedings should be sent to the Electrical Engineering Department, Imperial College of Science and Technology, London, S.W.7, and will be met as equitably as possible from the limited number available.

621.39.09 **985**

Frequency Compression.—P. Marcou. (*Ann. Télécommun.*, Oct. 1950, Vol. 5, No. 10, pp. 321–337.) Paper presented at the conference at the Sorbonne, April/May 1950, on Signal and Information Theory. Simple compression of a frequency spectrum involves an increase in transmission time. To avoid this the signal must be suitably 'cut' before compression. A theoretical analysis of this principle is given. The conditions which must be satisfied for intelligibility not to be lost and the effect of compression on different instantaneous frequency components of the signal are investigated. Theoretically, compression by frequency division, with subsequent multiplication on reception, is a satisfactory solution of the problem of narrow-band transmission. See also 3155 of 1950 (Loeb).

621.396.82 : 621.396.41 **986**

Interference in Multi-Channel Circuits.—L. Lewin. (*Wireless Engr*, Dec. 1950, Vol. 27, No. 327, pp. 294–304.) A detailed mathematical analysis of the interference in multichannel systems due to nonlinear relations between the input and output signals. Assuming an output/input relation which is a power series of the input signal, suitably delayed, the harmonic content of the output corresponding to a single pure-tone signal is found and compared with the interchannel interference when many channels are operative. In general, groups of interference products which are not random in phase are produced and a complex analysis is necessary to deduce the resultant interference from the intensities of the various harmonics. The standard method of measurement is justified only when the higher harmonics are negligible compared with the second and third orders. Distortion due to mismatches on a long feeder line is examined in detail; under such conditions the total interference may be appreciable when the absolute values of the lower harmonics are only small.

621.396.931/.932 **987**

Planning V.H.F. Mobile Systems.—E. G. Hamer: E. R. Burroughes. (*Electronic Engng*, Nov. 1950, Vol. 22, No. 273, p. 483.) Comment on 2629 of 1950 and author's reply.

621.396.931 **988**

Multiplex Design.—F. B. Gunter. (*FM-TV*, Nov. 1950, Vol. 10, No. 11, pp. 16–18.) The Westinghouse Type-FB f.m. multiplex transmitter/receiver for operation in the 960-Mc/s band is described, photographs and sectional and circuit diagrams being included. Both sender and receiver are crystal-controlled. Up to 7 speech channels are available, with a r.f. output power into the aerial of 5 W and an overall distortion $<1\%$.

621.396.931 **989**

Design of Mobile Radio Communication Equipment for Land/Mobile Services operating on Frequencies between 152–174 Mc/s.—R. A. Beers, W. A. Harris & A. D. Zappacosta. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part II, pp. 1232–1239.) The rapid increase of the number of systems using the frequency band 152–174 Mc/s, and the problems resulting from this increase, are discussed briefly. Equipment is described that has been designed to double the number of channels that can be used in any one locality.

621.396.931 : 624.193 **990**

Transmission through Tunnels.—J. B. L. Foot. (*Wireless World*, Dec. 1950, Vol. 56, No. 12, pp. 456–458.) Report of tests by the G.E.C. Research Laboratories in railway tunnels, with the object of communication between signal boxes and moving trains. Frequencies of 82, 460 and 1 400 Mc/s were used. At the lower

frequencies the tunnel attenuation is high, while the higher frequencies offer a practical solution of the problem, though the use of frequencies above about 500 Mc/s would probably introduce equipment problems and increase the cost.

621.396.619.13 **991**

Frequency Modulation. [Book Review]—K. R. Sturley. Publishers: Chemical Publishing Co., Brooklyn, U.S.A., 94 pp., $4.75. (*Radio & Televis. News*, Oct. 1950, Vol. 44, No. 4, p. 126.) Designed for the radio technician, this book, although small, "manages to convey an amazing amount of information on the subject". The treatment is largely mathematical.

SUBSIDIARY APPARATUS

621-526 **992**

An Analysis of Relay Servomechanisms.—D. A. Kahn. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part II, pp. 1079–1087. Discussion, pp. 1087–1088.) Full paper. Summary abstracted in 1252 of 1950.

621-526 **993**

Carrier Compensation for Servomechanisms.—H. E. Blanton. (*J. Franklin Inst.*, Nov. & Dec. 1950, Vol. 250, Nos. 5 & 6, pp. 391–407 & 525–542.) The problems involved in the provision of compensation to improve the stability and performance of systems using carrier-frequency techniques for data transmission are described. The theoretical forms of the compensation transfer characteristic for both amplitude and phase response with frequency are deduced and compared with the characteristics normally obtained from realizable circuits. The accuracy of the latter is limited by component tolerances and dependence on the stability of the carrier frequency. The various types of passive electrical network for obtaining desired carrier-compensation transfer characteristics are discussed. The main disadvantage of passive RLC networks is the nonlinearity introduced by the actual inductances used; such networks have, however, many distinct advantages.

621.314.6 **994**

Representation and Generalized Basis of Calculation for Rectifiers with Buffer Capacitors.—H. Verse. (*Bull. schweiz. elektrotech. Ver.*, 15th Oct. 1949, Vol. 40, No. 21, pp. 818–826. In German.) Rectifiers of this type are used commonly for supplying anode voltage in communications, h.f. and measurement apparatus, etc. The circuits are compared with those using inductance coils; the basic half-wave rectifier is discussed in detail, and more complex arrangements are examined by means of equivalent circuits. A simple general method of calculation based on graphical data is developed, and a numerical example is worked out.

621.314.63 : 621.317.335.2 **995**

An Oscillographic Method for the Investigation of Dry-Rectifier Barrier Layers.—Hoffmann. (See 941.)

621.314.63 : 621.317.335.2 **996**

A New Method of Capacity Measurement on Dry Disk Rectifiers.—Lehovec. (See 940.)

621.314.632.1† **997**

Conductivity Contour of the Barrier Layer in the Copper-Oxide Rectifier, as obtained from H.F. Measurements, and its Ordering into Space-Charge Zones.—G. Pfotzer. (*Z. Naturf.*, Dec. 1949, Vol. 4a, No. 9, pp. 691–706.)

621.316.93 **998**

Performance Characteristics of Lightning Protective Devices.—(*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part II, pp. 1333–1336. Discussion, p. 1336.) Combines in one report the data on lightning arresters of various types published previously by the A.I.E.E. Lightning Protective Devices Subcommittee in a number of separate reports, with such modifications as are required to bring the material up to date. In addition, data covering line expulsion-type arresters, and data on rod-gap spark-over voltages, are included for co-ordination with lightning-arrester characteristics.

621.319.332 **999**

New 200 000-V Electrostatic Generators.—P. Hémardinquer. (*Elektron, Linz*, 1950, No. 11, pp. 360–361, 386.) A brief account, taken from *Électricité*, Oct. 1950, of an influence machine developed at the Laboratoire National de la Recherche Scientifique and commercially available. A rotor with metal segments of thickness 2–6 mm revolves inside a sealed container under a pressure of 25–30 atm., this increased pressure multiplying the power 200-fold. Currents up to 10 mA can be supplied, and power output, not voltage, is proportional to size. The rotor can be driven by any convenient means. The machine is robust and cheap, and is suitable for operating electron microscopes and television apparatus as well as for agricultural and medical applications.

621.319.339 : 621.316.722 **1000**

Voltage Regulation for Van de Graaff Electrostatic Generators.—J. Taieb. (*Onde élect.*, Nov. 1950, Vol. 30, No. 284, pp. 462–468.) Discussion of different methods in use for stabilizing potentials of several million volts, and description of the system proposed for the 5-MV generator under construction for the French Atomic Energy Commission.

621.396.682 : 621.316.935.1 **1001**

Voltage Doubler with Saturable Reactor.—R. Aschen. (*Radio franç.*, Oct. 1950, No. 10, pp. 5–8.) In the arrangement described the basic voltage doubler is modified by inclusion of (*a*) a stabilizing saturable reactor whose impedance decreases as the current through it increases, (*b*) a circuit to protect the electrolytic capacitors from application of reverse voltage in case of failure of one of the rectifier diodes, and (*c*) a diode circuit for stabilizing the d.c. output. Some design details are given.

TELEVISION AND PHOTOTELEGRAPHY

621.385.832 : 535.37 **1002**

Color Cathode-Ray Tube with Three Phosphor Bands.—C. S. Szegho. (*J. Soc. Mot. Pict. Televis. Engrs*, Oct. 1950, Vol. 55, No. 4, pp. 367–376.) The screen of a c.r. tube for projection colour television has three phosphor bands fluorescing respectively in red, blue and green. The tube is suitable for use with field- or line-sequential transmissions; in the former case the bands are arranged one below the other, in the latter case side by side. The resulting three images are superimposed by the optical projection system. There are two inherent drawbacks: the screen area is inefficiently used from the standpoint of light output, and the resolution is inadequate.

621.397.5 : 535.623 **1003**

Color Television.—F. H. McIntosh & A. F. Inglis. (*J. Soc. Mot. Pict. Televis. Engrs*, Oct. 1950, Vol. 55, No. 4, pp. 343–366.) The field-sequential (C.B.S.), line-sequential (C.T.I.) and dot-sequential (R.C.A.) systems are compared from the point of view of service to the public. An addendum deals briefly with the frequency-interlace system (G.E.C.) and the 'Uniplex' system (C.T.I.). See also 249 of January.

621.397.5 : 535.623 **1004**

Colour Television: Frequency-Interlace System.—A. Dinsdale. (*Wireless World*, Dec. 1950, Vol. 56, No. 12, pp. 443–449.) A description of the system proposed by Dome (466 of February), based on data supplied to the F.C.C. by the General Electric Company.

621.397.5 : 621.315.212 **1005**

Television Terminals for Coaxial Systems.—L. W. Morrison, Jr. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part II, pp. 1193–1199.) Full paper. Summary abstracted in 1267 of 1950.

621.397.5 : 778.5 **1006**

Video Recordings Improved by the Use of Continuously Moving Film.—W. D. Kemp. (*Tele-Tech*, Nov. 1950, Vol. 9, No. 11, pp. 32–35..63.) Detailed description of B.B.C. technique. The film moves continuously, but optical compensation methods are used to obtain a succession of separate pictures as with ordinary cinema film. Details of these methods are given. The system is normally used to record at 25 frames/sec from a television picture with a repetition rate of 25/sec, but a simple modification permits recording at 24 frames/sec from a picture with repetition rate 30/sec. Application of a 10–15-Mc/s sine-wave deflection voltage to the scanning beam reduces line structure in the record.

621.397.5 : 778.5 **1007**

Comparative Study of the Techniques for Recording and Reproducing Moving Images by Cinematography and by Television.—M. J. de Cadenet. (*Ann. Télécommun.*, Nov. & Dec. 1950, Vol. 5, Nos. 11 & 12, pp. 389–404 & 406–416.)

621.397.5(083.74) **1008**

Australian Television Standards.—(*Proc. Instn Radio Engrs, Aust.*, Nov. 1950, Vol. 11, No. 11, pp. 289–291.) Details of the standards determined by the Australian Broadcasting Control Board are given.

621.397.743 : 621.392.5 : 621.315.212 **1009**

Equalization of Coaxial Lines.—Gould. (See 836.)

621.397.8 **1010**

The Range of the 819-Line Television Transmitter at Lille.—(*Radio prof., Paris*, Oct. 1950, Vol. 19, No. 188, p. 15.) Rough chart of the service area. Peak power for vision is 200 W; carrier power for the sound channel 35 W. Vision signals are received 94 km (58 miles) to the E.N.E., in which direction the aerial has a power gain of about 10.

621.397.5 **1011**

Practical Television Engineering. [Book Review]—S. Helt. Publishers: Murray Hill Books, New York, 694 pp., $7.50. (*Radio & Televis. News*, Oct. 1950, Vol. 44, No. 4, p. 124.) A comprehensive treatment designed for manufacturing, sales and broadcasting engineers, students, and technicians.

TRANSMISSION

621.396.619 : 621.392.26† : 621.396.615.141.2 **1012**

The Development of Modulation on Waveguides.—J. Ortusi & P. Fechner. (*Ann. Radioélect.*, Oct. 1950, Vol. 5, No. 22, pp. 331–338.) Modulation of the energy fed along a waveguide by means of a magnetron coupled to it by a coaxial line was described in 54 of 1948 (Gutton & Ortusi). The design of the magnetron is discussed in relation to modulation factor and bandwidth; a magnetron with grooves linking the cavities is described. Static and dynamic impedance and conditions for minimizing losses are considered. The influence on the interelectrode h.f. field of various parameters is investigated, and space-charge resonance is studied as a function of d.c. magnetic field and anode potential. Application to a television transmitter operating on a carrier wavelength of 23 cm with modulation frequencies up to 30 Mc/s is described.

VALVES AND THERMIONICS

537.525.92 : 537.533 : 621.385.832 **1013**

Space-Charge Effects in Electron Beams and their Reduction by Positive-Ion Trapping.—E. G. Linder & K. G. Hernqvist. (*J. appl. Phys.*, Nov. 1950, Vol. 21, No. 11, pp. 1088–1097.) "An equilibrium condition may be established in which the electron and ion densities are equal, and then space-charge forces will be neutralized. Under these conditions high current densities may be produced at low voltages. A theory of ion trapping is discussed, and the equilibrium condition is formulated. Experimental data are presented which were obtained by the application of microsecond pulses to the beam. This technique is described, and its advantages and possibilities are mentioned. Data are given on beam spread as a function of current, voltage and pressure. Data on the improvement due to ion trapping are included. An increase of current density by a factor of 30 was observed with the structures tested. Results are included on ion build-up time as a function of pressure, and on beam noise and stability in the presence of trapped ions."

537.533.8 : 621.396.615.14 **1014**

On the Time Delay of Secondary Emission.—G. Diemer & J. L. H. Jonker. (*Philips Res. Rep.*, June 1950, Vol. 5, No. 3, pp. 161–172.) The upper frequency limit of a disk-seal dynatron is found to be 2·4 kMc/s; from this an upper limit of 3×10^{-11} sec is deduced for the time lag τ of secondary-electron emission. Measurements of the admittance of an u.h.f. dynatron at 300 Mc/s indicate that τ is $< 10^{-11}$ sec; an upper limit of the order of 10^{-14} to 10^{-15} sec can be estimated theoretically from transit-time effects within the secondary-emission material.

621.314.653 **1015**

The Ignitron and its Applications.—R. David & C. Caussin. (*Onde élect.*, Nov. 1950, Vol. 30, No. 284, pp. 476–484.) Both sealed and vacuum-maintained types are discussed and practical applications as rectifier elements and as inertialess contactors are described.

621.383 : 621.387.4† **1016**

Multiplier Phototubes in Scintillation Counters.—R. E. B. Hickman. (*Electronic Engng*, Nov. 1950, Vol. 22, No. 273, pp. 474–476.) The advantages and the principles of operation of scintillation counters using multiplier photocells are discussed and the principal characteristics of Types 931A, IP21, IP22, IP28 and 5819 photocells are tabulated.

621.385.029.63/.64 + 621.384.62 **1017**

The Control of Electron Streams by means of Progressive Waves (Travelling-Wave Tubes).—O. Döhler. (*Funk u. Ton*, Oct. 1950, Vol. 4, No. 10, pp. 493–507.) Description of the principle of the travelling-wave oscillograph and accelerator and theoretical analysis of the operation of the Kompfner-Pierce type of travelling-wave valve.

621.385.029.63/.64 **1018**

H.F. Amplification by Interaction of Two Electron Beams.—J. Labus. (*Arch. elekt. Übertragung*, Sept. 1950, Vol. 4, No. 9, pp. 353–360.) A physical explanation is developed of the operation of parallel-beam valves. The theory leads to a boundary-value problem

whose solution yields four eigenvalues, indicating a coupling action between the two beams via their common e.m. field. To confirm this, an arrangement is investigated in which the two beams are separated coaxial hollow cylinders; amplification increases with tightness of coupling. Because of the elastic properties of the electron charges within the stream, two waves with different phase velocities are propagated.

621.385.029.63/.64 **1019**

The Active Coaxial Tube.—P. A. Clavier. (*Phys. Rev.*, 15th Jan. 1950, Vol. 77, No. 2, p. 302.) The possibility indicated by Roberts (608 of 1950) of obtaining gain in a travelling-wave valve in the direction opposite to that of the electron beam is confirmed. Considering a waveguide traversed by a beam, the gain parameters have been derived as functions of the Larmor frequency, the electron plasma frequency, the wavelength, and the guide diameter. The importance of proper matching is emphasized.

621.385.029.63/.64 **1020**

On the Properties of Valves using a Constant Magnetic Field: Travelling-Wave Valves with Magnetic Field: Part 4.—O. Doehler, J. Brossart & G. Mourier. (*Ann. Radioélect.*, Oct. 1950, Vol. 5, No. 22, pp. 293–307.) Linear theory given in part 3 [1544 of 1949 (Brossart & Doehler)] is developed further, and a more exact calculation is made of the small-signal gain. Two further wave modes are found; these undergo neither amplification nor attenuation. The major cause of nonlinear effects is anode absorption. Efficiency is higher for beam injection potentials small compared with anode potential; a simple expression is given for the efficiency in that case.

621.385.029.63/.64 : 537.533.7 **1021**

Dynamic Electron Flow under the Influence of Dynamic Fields.—König. (See 854.)

621.385.029.63/.64 : 621.396.615.141.2 **1022**

Space-Charge Effects in Magnetic-Field Travelling-Wave Valves.—R. Warnecke, O. Doehler & D. Bobot. (*Ann. Radioélect.*, Oct. 1950, Vol. 5, No. 22, pp. 279–292.) Development of discussion on the type of valve previously described [2064 of 1950 (Warnecke et al.)], where space-charge effects were assumed negligible. Actual measurements, e.g. of anode current as a function of magnetic field, do not agree with results to be expected from classical theory; the discrepancies are ascribed to interaction between electrons moving with different velocities [see 333 of 1950 (Warnecke et al.)], which give rise to amplification of oscillations. This effect is investigated analytically and confirmed for a valve with slotted delay line [1584 of 1949 (Brillouin)]. The effect of space charge itself is negligible.

621.385.15 **1023**

Statistical Theory of Electron Multipliers.—F. Sauter. (*Z. Naturf.*, Dec. 1949, Vol. 4a, No. 9, pp. 682–691.)

621.385.032.213.1.017.72 **1024**

End-Cooling of Power-Tube Filaments.—J. W. Clark & R. E. Neuber. (*J. appl. Phys.*, Nov. 1950, Vol. 21, No. 11, pp. 1084–1087.) "The differential equation defining the relation between temperature and distance in that portion of a vacuum tube filament which is cooled by both conduction and radiation is formulated. This equation has been solved by numerical integration; the results are presented as a set of universal curves in a form convenient for use in vacuum tube design. The calculations agree well with some experimental measurements which were made to verify the theory."

621.385.032.216 **1025**

Effect of Coating Composition of Oxide-Coated Cathodes on Electron Emission.—E. G. Widell & R. A. Hellar. (*J. appl. Phys.*, Nov. 1950, Vol. 21, No. 11, pp. 1115–1118.) Experiments indicate that maximum electron emission under saturation conditions is obtained from a solid solution containing SrO and BaO in a molecular ratio of about 7 : 3. Maximum size of the coprecipitated carbonate particles is obtained with the same ratio of constituents. Valves with such cathode coatings showed no measurable electron-emission decay for a pulse duration of 10 μs.

621.385.032.216 **1026**

The Spectral Emittance of Nickel and Oxide-Coated-Nickel Cathodes.—S. L. Martin & G. F. Weston. (*Brit. J. appl. Phys.*, Dec. 1950, Vol. 1, No. 12, pp. 318–324.) Knowledge of the emittance is required to derive the cathode temperature from the observed brightness. Values at a wavelength of 0·66 μ have been measured for various oxide-coated cathodes and for nickel cores. The effects of stoving or baking treatment, temperature, getter flash and (in oxide-coated cathodes) surface texture are discussed.

621.385.032.216 : 535.215 **1027**

Photoelectric Effect in Oxide Cathodes.—J. Debiesse & R. Champeix. (*Le Vide*, Jan. 1949, Vol. 4, No. 19, pp. 545–552.) A recapitulation is given of results of experiments reported previously (607 and 1817 of 1948). Treatment of oxide cathodes encouraging thermionic emission reduces their photoelectric sensitivity. Simple calculations of the numbers of photons, electrons, Ba atoms and oxide molecules involved in the mechanism tend to show that the phenomena observed are due to a combination of photoelectric effect and variation of conductivity of the oxide layer. The loss of photosensitivity following thermal activation is attributed to an excess of Ba atoms at the surface, as previously suggested by de Boer.

621.385.032.216.2 **1028**

Base-Metal Effects in Thoria-Coated Filaments.—H. Nelson. (*J. appl. Phys.*, Nov. 1950, Vol. 21, No. 11, pp. 1194–1195.) Adherence of thoria to the metal filament is good for Pt but poor for W, as expected from the relative coefficients of thermal expansion. It is to be expected that a stoichiometric excess of metal in the crystal lattice of the thoria is associated with a low work function; experiment provided confirmation of this, higher thermionic activity being observed for a Ta base than a Pt base, since Ta is a better reducing agent.

621.385.032.3 **1029**

The Length of Life of an Incandescent Tungsten Spiral and the Rate of Evaporation of Tungsten in High Vacuum.—E. Baş-Taymaz. (*Z. angew. Phys.*, 15th Sept. 1950, Vol. 2, No. 9, pp. 374–376.)

621.385.5 : 621.318.572 **1030**

A 30-Element Electrostatically-Focused Radial Beam Tube.—A. M. Skellett & P. W. Charton. (*Tele-Tech*, Nov. 1950, Vol. 9, No. 11, pp. 26–27..59.) Description of a valve for high-speed sequential switching, using beam deflection. Two types are available, one having all the grids except one connected together and separate anode leads, the other having all the anodes except one strapped and separate grid leads. Each of the 30 sections has a transconductance of 12 μmhos, a 5-MΩ anode load, and an amplification factor of 60. Normal operating conditions are: anode voltage 450 V, beam current 60 μA, cathode bias 76 V, and a 6-phase deflection voltage of 300 V r.m.s. Crosstalk does not exceed −30 db and sweep speeds up to 10^6/sec are possible.

621.385.832 **1031**

Fundamentals and Applications of Colour-Trace Tubes [Farbschriftröhren].—P. G. Violet. (*Funk u. Ton*, Oct. 1950, Vol. 4, No. 10, pp. 530–543.) German war-time development of a type of dark-trace tube is described. The screen has a coating of microcrystalline KCl, which develops red to dark-blue coloration according to the intensity of the incident radiation. The coloration disappears on warming, which is effected by electrical heating of an adjacent, very thin, transparent layer of tungsten. Other methods of obliterating the trace are 'wiping' the screen at much greater intensity or applying an electric field. Using a 4-mm trace with resolution 1 : 150, trace velocities of 100 m/s are attainable. Applications of these tubes in communication, measurement, facsimile, and colour-television systems are described and discussed.

621.385.832 **1032**

An 'Ideal' Post Deflexion Accelerator C.R.T.—L. S. Allard. (*Electronic Engng*, Nov. 1950, Vol. 22, No. 273, pp. 461–463.) The final accelerating field is introduced between two parallel sheets of wire gauze placed very near and parallel to the fluorescent screen. In this way the deflector-plate sensitivity is unaffected and scan distortion is completely eliminated, but owing to the emission of secondary electrons the resolution and contrast range are reduced. The author considers that the disadvantages of the tube outweigh its advantages for commercial use. See also 2397 of 1949 (White).

621.385.832 : 517.51 : 681.142 **1033**

The Monoformer.—A. C. Munster. (*Radio & Televis. News, Radio-Electronic Engng*, Oct. 1950, Vol. 15, No. 4, pp. 8A–9A.) Description of a device which may be used to provide a signal corresponding to any single-valued function to an accuracy within 1%. A small e.s. c.r. tube is used in which the phosphor screen is replaced by an Al target disc on which the desired function is represented by the boundary of a carbon-ink coating. A simple feedback loop connects the target and the y deflection-plates. When independent signals are applied to the x plates the electron beam traces the boundary line and an output representing the desired function is obtained at the y plates. Applications in analogue computers, volume compressors and expanders, and waveform generators, are mentioned. See also 1355 (No. 88) and 2814 of 1950 (Schultz, Calvert & Buell).

621.385.832 : 681.142 **1034**

Electrostatic Storage Tube.—S. H. Dodd, H. Klemperer & P. Youtz. (*Elect. Engng, N.Y.*, Nov. 1950, Vol. 69, No. 11, pp. 990–995.) "A beam-deflection electrostatic tube has been developed to store binary-coded information at two stable potential levels, 100 V apart, for digital computers or communications systems. A single 2 000-V electron beam writes or reads one of 400 binary digits on a 4-in. target. A 100-V electron flood replaces leakage and retains stored information indefinitely. The potential boundary stability on the storage surface is assured by a mosaic of conducting beryllium squares."

621.396.615.141.2 : 621.396.619 : 621.392.26† **1035**

The Development of Modulation on Waveguides.—Ortusi & Fechner. (See 1012.)

621.396.615.142 **1036**

The Generation of Electromagnetic Oscillations in V.M. Valves with High Efficiency.—R. Gebauer. (*Z. angew. Phys.*, Oct. 1950, Vol. 2, No. 10, pp. 415–422.) Valves of the type having two oppositely phased h.f. gaps are considered, and the relation between drift-path length, h.f. modulation depth and overall efficiency is studied both theoretically and experimentally. Formulae are developed in a form independent of frequency and operating voltage; these enable the efficiency of a given arrangement to be estimated, and also enable valves to be designed rapidly with a given efficiency. A valve designed for 50% efficiency at a wavelength of 27 cm and 230-V operating voltage gave a measured efficiency of 49·6%, the highest yet obtained with a drift-space valve. The most effective direction for the beam is at an angle of 1·5° with the axis. The relation between h.f. power and d.c. power is also studied.

621.396.645 : 621.315.592† : 537.311.33 **1037**

The Amplification Observed in Semiconductors.—H. F. Mataré. (*Onde élect.*, Nov. 1950, Vol. 30, No. 284, pp. 469–475.) To obtain a quantitative idea of the phenomenon of transistance, comparative measurements were made at 60 Mc/s of emitter, collector and transfer resistance and capacitance for two mechanically identical Ge crystal triodes of which one, the transistron (see 2978 of 1949), exhibited amplification while the other did not. The results are shown graphically as functions of emitter current, and are discussed. Calculations based on the results yield values for the concentration of impurity centres consistent with Bardeen & Brattain's theory (264 of 1949) that the emitter current is carried by holes. A matrix analysis of the transistron considered as a quadripole is included.

621.396.822 **1038**

Transit-Time Phenomena in Electron Streams: Part 2.—D. K. C. MacDonald. (*Phil. Mag.*, Sept. 1950, Vol. 41, No. 320, pp. 863–872.) "A density modulated electron stream will suffer amplitude reduction and phase variation with transit time due to the statistical velocity distribution of the electrons. The problem is considered in relation to that of noise generation in a beam due to velocity fluctuation; the analysis developed is then used in examining the variation of space-charge reduction factor (Γ^2) under particular laws of potential distribution which present themselves in physical problems." See also 2408 of 1949.

621.385 **1039**

Electron Tubes, Vols. 1 & 2. [Book Review]—Publishers: R.C.A. Reviews, Princeton, N.J., 1949, 475 pp. and 453 pp., $2.50 each. (*Electronic Engng*, Nov. 1950, Vol. 22, No. 273, p. 487.) A collection of papers published by R.C.A. research workers. Vol. 1 covers the period 1935–1941 and includes 15 main papers, while the 21 main papers of Vol. 2 were published in the period 1942–1948.

MISCELLANEOUS

519.283 : 658.562 **1040**

Statistical Methods in Research and Development.—L. Lutzker. (*Proc. Inst. Radio Engrs*, Nov. 1950, Vol. 38, No. 11, pp. 1253–1257.) 1950 I.R.E. National Convention paper noted in 1559 of 1950 (No. 22).

621.39 Heaviside **1041**

The Centenary of the Birth of Oliver Heaviside.—L. Bouthillon. (*Onde élect.*, Oct. 1950, Vol. 30, No. 283, p. 394.) Papers read at a commemorative meeting at the Sorbonne, May 1950, are noted; these are given in full on pp. 395–415 of the journal and include tributes by L. de Broglie, E. Picault, P. Humbert, S. Colombo, P. M. Prache, L. Bouthillon, E. Appleton (representing the Royal Society) and W. Jackson (representing the Institution of Electrical Engineers).

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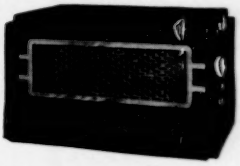

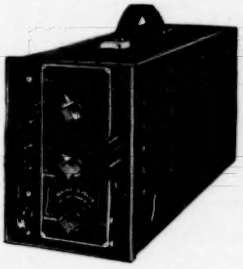

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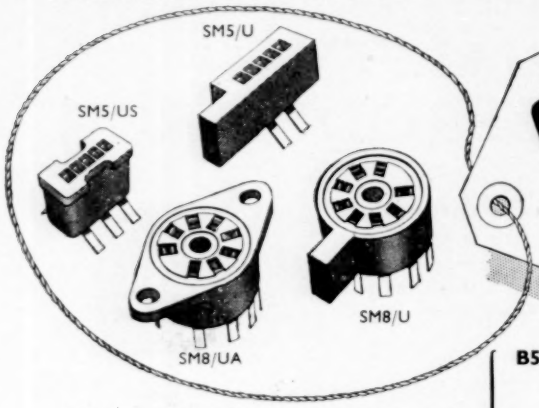

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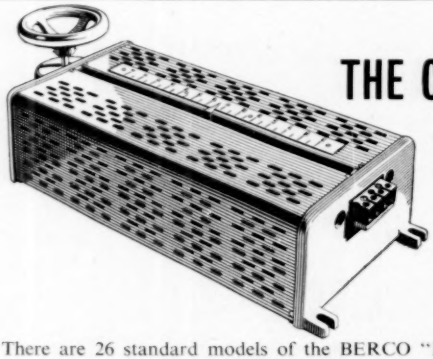

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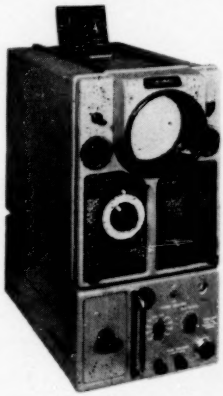

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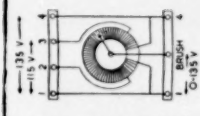
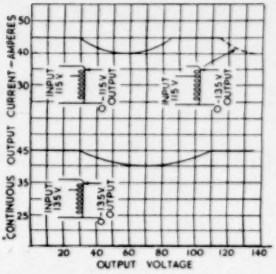
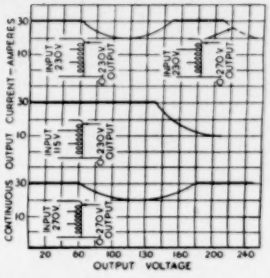
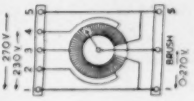


OUTPUT CURRENT CHARACTERISTIC AND TERMINAL ARRANGEMENT FOR TYPE 50-A TRANSFORMER







OUTPUT CURRENT CHARACTERISTIC AND TERMINAL ARRANGEMENT FOR TYPE 50-B TRANSFORMER

SPECIFICATIONS							
TYPE	LOAD RATING	INPUT VOLTAGE	CURRENT		OUTPUT VOLTAGE	NO-LOAD LOSS	NET PRICE £ s. d.
			RATED	MAXIMUM			
50-A	5 kva.	115 v.	40 a.	45 a.	0-135 v.	65 watts	44 18 6
50-B	7 kva.	230/115 v.	20 a.	31 a.	0-270 v.	90 watts	44 18 6

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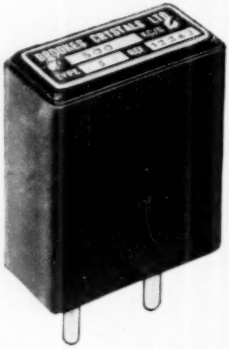

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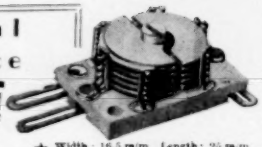

★ Width: 16.5 m/m Length: 25 m/m Height:
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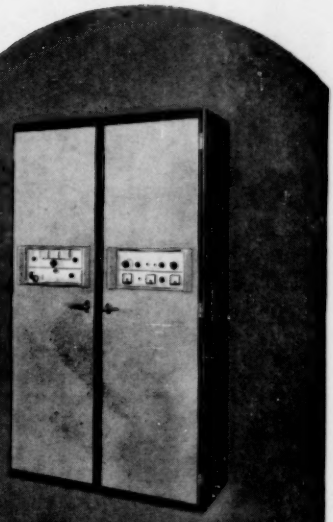

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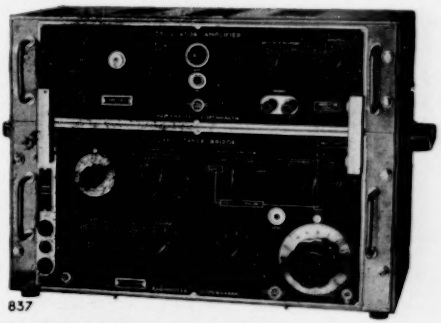

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4 (a) This is a standard "Lectropack" normally used with two-hole clip fixing.

4 (b) Shows a specially developed T.P. clip. This is eminently suitable for making use of standard construction condensers held in stock — or for replacement purposes; for 1¾" diameter cans only.

5 This shows T.P. clip (4.b.) fitted to standard "Lectropack" condenser (4.a.).

TCC

NOTE: ***The usual practice with T.P. mounting condensers is for the negative connection to be via the aluminium can. The cheapest way of doing this is to clip a strip of aluminium foil into the lip of the can during the closing operation but this leads to open-circuits due to chafing or cutting through the strip.***

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Alloy	Colour Code	Sol.	Liq.	Bal. Temp.	USES
60/40	Red	183° C	190° C	230° C	High quality work
45/55	Crimson Band	183° C	227° C	267° C	Hand Soldering
40/60	Green	183° C	238° C	278° C	radio and electrical

Ersin Multicore Solder is made as standard for factory use in 6 alloys and 9 gauges, and is supplied on nominal 7 lb. reels. Other alloys and gauges can be supplied to special order. Bulk prices on application.

GAUGES. Approximate number of feet per lb. (2.2% flux content).

Standard Wire Gauge	Diam. in inches	Diam. in m.m.	ALLOY Tin content is shown first 60/40	45/55	40/60
10	.128	3.251	24.1	23.2	23.7
12	.104	2.642	37.2	35.2	34.6
13	.092	2.337	47.3	45	44
14	.080	2.032	62.8	59.4	58
16	.064	1.626	98	93	91
18	.048	1.219	174.5	165	161
19	.040	1.016	251	238	233
20	.036	.914	310	294	287
22	.028	.711	512	486	474

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